Assessing the usability of virtual learning environments in higher education

By

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Abstract

Context: E-learning is an integral part of the modern higher education system, and therefore it is essential that students and staff are able to use systems that support E-learning, such as Virtual Learning Environments (VLEs), effectively. Usability is essential to ensure effective use of these systems and is often assessed by means of subjective questions. Although developed mainly for industry use, the Technology Acceptance Model (TAM) and System Usability Scale (SUS) questionnaire are often used to assess E-learning systems.

Goal: The main goal of this thesis is to assess the usability of a VLE platform currently used in universities (Blackboard) and identify the most common and appropriate methods used to assess a VLE platform's usability. Another aim is to investigate whether there are extensions to common usability models and methods (such as the SUS and TAM) that could improve their accuracy, including the potential of combining them with more objective measures such as number of clicks, time taken and open-ended questions.

Method: The literature on VLE usability evaluation was reviewed using a mapping study methodology to identify the usability methods and factors that have been used previously. Informed by the findings of this study, a set of usability questionnaires have been developed, used and evaluated, with 101 student respondents recruited from all the Schools at Keele University participating in the first study (Chapter Four) and 162 in the second study (Chapter Five). A standard usability questionnaire and a novel form of observation were then combined to record 25 participants' interactions with the VLE (Chapter Six) while they completed a set of representative tasks in two sessions that were held eight weeks apart. These interactions were then compared.

Results: The results indicate that the VLE performed below the average usability expectation score (SUS score of 62.52) but is still considered as 'acceptable'. Twenty-seven free text responses were also obtained in the first study and a thematic analysis of comments revealed

very negative views of the VLE as well as areas for improvement. In the second study, it was found that perceived enjoyment (PE) and usability were jointly related to the perceived usefulness (PU), although the association was relatively weak. Perceived enjoyment and learnability were jointly associated with perceived ease of use (PEOU), with the association accounting for 39% of the variation in PEOU. Usability was related to PE but learnability was not. Overall, the original TAM can be improved by the addition of learnability, PE and usability as they have a positive effect on TAM. In the final study, the task success rate was relatively high (i.e. 82.3% in session 1); however, an average participant took 3.6 times longer to complete the set of tasks than a competent user. Furthermore, task time, clicks and success rate improved only marginally in the second session (which was at the end of the semester). However, when compared with the analysis of the results from the standard usability questionnaires (subjective measures), participants stated that they were satisfied with the usability of the system, contradicting the objective measures (number of clicks, task time and success rate).

Conclusions: Using subjective measures alone, in the form of standard usability questionnaires, to assess the usability of a complex system can conceal significant issues. Usability assessment should therefore be based on actual performance against a defined baseline and combined with forms of qualitative feedback such as free text responses. Evaluating the effect of usability on E-learning is complicated. The studies conducted in this thesis have provided valuable guidance on how to measure the usability of VLEs. Suggestions for future work on the usability of VLEs as well as appropriate recommendations are provided.

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Author's Declaration

I certify that this thesis submitted for the degree of Doctor of Philosophy is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution

Disseminations

In the context of the PhD. a significant part of work has already been published or submitted for publication. This following section presents details of papers, seminar activities and posters:

Refereed Conference Papers

- **Abuhlfaia, K., de Quincey, E. 2019 "**Evaluating the Usability of an E-learning Platform within Higher Education from a Student Perspective,**". In Proceedings of the 2019 3rd International Conference on Education and E-Learning (pp. 1-7). https://doi.org/10.1145/3371647.3371661.**

- **Abuhlfaia, K., de Quincey, E., 2018. "**The usability of E-learning platforms in higher education: a systematic mapping study,**". Proceedings of the 32nd International BCS Human-Computer Interaction Conference. https://dx.doi.org:10.14236/ewic/HCI2018.7**

- **Abuhlfaia, K., & Quincey, E. 2017** "How does the usability of learning technologies affect learners?"**[1737]. The 24th annual conference of the Association for Learning Technology, 5 – 7 September 2017, University of Liverpool, UK. https://altc.alt.ac.uk/2017/sessions/how-does-the-usability-of-learning-technologies-affect-learners-1737/#gref**

Papers under review

- **Abuhlfaia, K., de Quincey, E., "**Measuring the Influence of Usability, Learnability and Perceived Enjoyment on Technology Acceptance,**".**

- **Abuhlfaia, K., de Quincey, E., Kitchenham, B., "**Usability evaluation of Virtual Learning Environments using subjective and objective measures,"

External Talks

- The usability of E-learning platforms in higher education: a systematic mapping study**. International BCS Human-Computer Interaction Conference (HCI 2018), Belfast, UK, July 2018.**

- Evaluating the Usability of an E-learning Platform within Higher Education from a Student Perspective. **The 3rd International Conference on Education and E-learning (ICEEL, 2019), Barcelona, Spain, November 5-7, 2019.**

- How does the usability of learning technologies affect learners?[**1737]. The 24th annual conference of the Association for Learning Technology, 5 – 7 September 2017, Liverpool, UK.**

Internal Talks

- The usability of E-learning platforms in higher education: a systematic mapping study**, the 7th Computing and Mathematics Postgraduate Research Day, Keele University, April 2017.**

- The usability of E-learning. A review**, The Faculty of Natural Sciences' Postgraduate Symposium, Keele University, May 2017.**

- Evaluating the Usability of an E-learning Platform within Higher Education from a Student Perspective**, 8th Computing and Mathematics Postgraduate Research Day, Keele University, April 2018.**

- Evaluating the Usability of an E-learning Platform within Higher Education from a Student Perspective**, The Faculty of Natural Sciences' Postgraduate Symposium, Keele University, May 2018.**

- **The u**sability evaluation of Virtual Learning Environments using subjective and objective measures**, 9th Computing and Mathematics Postgraduate Research Day, Keele University, April 2019.**

- The usability evaluation of Virtual Learning Environments using subjective and objective measures**, The Faculty of Natural Sciences' Postgraduate Symposium, Keele University, May 2019.**

Posters

- The usability of E-learning platforms in higher education: a systematic mapping study**, The University of Central Lancashire Postgraduate Symposium, Preston, UK, November 2016.**

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List of Abbreviations

ACM	Association for Computing Machinery
ATB	Attitude Towards Behaviour
CMS	Course Management System
E-banking	Electronic-banking
E-commerce	Electronic-commerce
E-learning	Electronic learning
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization Standardization
IU	Intention to Use
JISC	Joint Information Systems Committee
KLE	Keele Learning Environment
LISREL	Linear Structural Relations
LMS	Learning Management Systems
Moodle	Modular Object-Oriented Dynamic Learning Environment
MRT	Mental Rotations Test
ODeL	Open Distance e-Learning
PE	Perceived Enjoyment
PEOU	Perceived Ease of Use
PLS	Partial Least Square
PU	Perceived Usefulness
QUIS	Questionnaire for User Interface Satisfaction
QUIS	Questionnaire for User Interface Satisfaction
RQ	Research Questions
SD	Standard Deviation
SEM	Structural Equation Modeling
SMC	Squared Multiple Correlation
SMS	Systematic Mapping Study
SPSS	Statistical Package for Social Sciences
SUMI	Software Usability Measurement Inventory
SUS	System Usability Scale
TAM	Technology Acceptance Model
TRA	Theory of Reasoned Action
UEMs	Usability Evaluation Methods
UK	United Kingdom
UTAUT	Unified Theory of Acceptance and Use of Technology
UX	User Experience
VIF	Variance Influence Factor

VLE	Virtual Learning Environment
WLUQ	Web-based Learning And Usability Questionnaire

Glossary

Some of the key terms used in this work that have been derived from multiple disciplines are defined below.

- **Effectiveness:** The students achieve a specific goal accurately using the VLE.
- **Efficiency:** The ability to use the VLE to perform specific tasks with minimal effort.
- **Error rate:** Using the VLE with minimal incorrect actions (such as inappropriate function calls or unnecessary or incorrect keyboard clicks) while performing a required task.
- **Learnability:** How easy or difficult it is for students to learn to use the VLE effectively.
- **Memorability:** The degree to which students can remember how to use the VLE.
- **Perceived ease of use (PEOU):** How the students perceive that using the VLE would be effortless.
- **Perceived enjoyment (PE):** Students discover activities that bring pleasure and enjoyment while using the VLE.
- **Perceived usefulness (PU):** The degree to which the students believe that using the VLE would enhance their study performance.
- **Satisfaction:** How pleasant and attractive the students find the VLE.
- **System Usability Scale (SUS):** A technology-independent ten-item scale for subjective evaluation of the usability of the VLE.
- **Task scenario:** Narrative description of how and why a student would interact with the VLE.
- **Task:** A procedure that includes goals, steps, skills, inputs and outputs to accomplish an activity on the VLE.
- **Usability evaluation:** A variety of techniques for measuring the usability of the VLE.
- **Usability:** How satisfactorily, effectively and efficiently the functions of the VLE can be used by a student.

Chapter 1 Introduction

1.1 Background and Motivation

The use of learning technology, commonly termed Electronic learning (E-learning) has become the new norm in higher education (Betts, 2017). E-learning is commonly defined as a number of activities that support learning and training that are delivered using computers and smart devices through the internet (Ardito et al., 2006; Sulaiman, Zulkifli, Ibrahim, & Noor, 2009). E-learning platforms are now an essential tool for universities and their users in learning and teaching (Ventayen, Estira, De Guzman, Cabaluna, & Espinosa, 2018). Traditionally, a learning environment used in higher education involves roles, strategy, organisation and guidelines (Entwistle, 2003). Due to its ubiquity, a virtual learning environment (VLE) is now considered as a common component of E-learning (Martín-Blas & Serrano-Fernández, 2009; Van Raaij & Schepers, 2008). A VLE is a tool designed to be used in education for learning proposes by providing support for learners' and providers' needs (Nurhudatiana, Hiu, & Ce, 2018; Van Raaij & Schepers, 2008). VLEs often involve different types of user roles, including students, instructors, course administrators and other roles (Nurhudatiana et al., 2018). They are used to improve the efficiency of communication between learners and their institution and support learning activities with functionality such as messaging, tasks, course content, chat rooms, assignments, quizzes, examinations and grades (Eldridge, 2014).

The Joint Information Systems Committee (JISC) stated that VLEs are now well established at universities and help to deliver learning content and activities, structuring and managing them (JISC, 2019). However, Newman and Beetham (2017) reported in the findings of the JISC Student Digital Experience Tracker survey that although nine out of ten students have access

to online course materials, the full advantages of using technology to support learning have not yet been realised.

A potential reason for this is the tools themselves, which have been criticised (Marković & Jovanović, 2012) as they often do not meet users' expectations, and it has been suggested that their effectiveness is one of the main factors that can affect a student's learning (Raspopovic, Jankulovic, Runic, & Lucic, 2014). Moreover, a number of studies have identified issues in existing E-learning systems, for example, user interface, design and navigation issues (Alturki & Aldraiweesh, 2016; Arshad, Majeed, & Afzal, 2016; Tee, Wook, & Zainudin, 2013; Vertesi, Dogan, Stefanidis, Ashton, & Drake, 2018).

It seems, therefore, that usability, although a well-known concept (Chu et al., 2020), is often neglected in the development of E-learning software (Abuhlfaia & de Quincey, 2019; Chu et al., 2020; Zaharias, 2009) even though it is considered as one of the factors that play a major role in the acceptance of the systems by users (Babić, 2012; Parsons, 2017). The cost of poor usability is high, with learners left feeling frustrated (Plata & Alado, 2009), and it has been shown to affect learning (Nurhudatiana et al., 2018; Van Raaij & Schepers, 2008). If users need time to become familiar with the functionality of the software as the system's usability is low, this may affect their focus on the module's main content (Costabile, De Marsico, Lanzilotti, Plantamura, & Roselli, 2005). If the platform were both interesting and usable, it would be much more useful to the user (Hassenzahl, Platz, Burmester, & Lehner, 2000), leading to engagement and greater satisfaction and keeping users' motivation levels high, which can reflect in their learning success (Ardito et al., 2006; Zaharias & Poylymenakou, 2009). Therefore, usability and its integration or participation in the learning process is an area considered worthy of further study (Zaharias, 2009).

Evaluating the usability of VLE systems is not a simple task (Abuhlfaia & de Quincey, 2019; De Leeuw et al., 2019) because of the nature of the evaluation methods required, which are commonly reliant on resource-intensive user participation (Arshad et al., 2016). For this reason, subjective assessment questionnaires, such as the System Usability Scale (SUS) and Questionnaire for User Interface Satisfaction (QUIS), are often used (Abuhlfaia and de Quincey, 2018; Mtebe & Kissaka, 2015). Systematic reviews conducted by Nakamura, de Oliveira and Conte (2017) and Abuhlfaia and de Quincey (2018) highlighted that there is a need for more investigation in this area as few studies focused on the effectiveness of the evaluation techniques themselves and provided specific suggestions to resolve the problems identified. Therefore, further investigation is required in different educational institutions and levels of education and with more learning platforms (Orfanou, Tselios, & Katsanos, 2015) using different usability evaluation techniques, preferably from the perspective of the user.

Consequently, the research described in this thesis focuses on identifying the best methods to assess the usability of E-learning applications and how these methods can be improved to take into account the user perspective. It is hoped that it will give researchers and designers of VLE systems specific guidance on how to make the applications more usable and methods to help them evaluate their products.

1.2 Research Purpose and Aims

The main purpose of this PhD research is to investigate the usability of VLEs and identify the best methods to use for evaluating their usability from the user perspective. The following are the specific aims of this research:

1. To identify the status quo in the area of evaluating the usability of VLEs used in higher education

2. To evaluate the usability of a commonly used VLE in higher education using the state-of-the-art methods

3. To identify specific usability issues that users have with current VLEs and produce a set of usability guidelines

4. To investigate whether there are extensions to current usability models and methods that could improve their effectiveness for evaluating the usability of VLEs

5. To identify the most appropriate and effective methods for evaluating the usability of VLEs

6. To investigate how usability attributes may change over time based on actual usage.

1.3 Research Questions

The aims described above are synthesised and addressed in five research questions.

RQ1: How can the usability of a VLE used in higher education be measured? (Aims 1–3).

RQ2: What are the important factors that influence the usability of the VLE in higher education? (Aims 1–3).

RQ3: What are the relationships between the common usability factors in the use of the VLE in higher education? (Aims 4 and 5).

RQ4: How do the different methods for measuring usability differ and is there a systematic difference between the output of different methods used to assess VLE usability? (Aims 5 and 6).

RQ5: Do the usability attributes change over time based on actual usage? (Aim 6).

1.4 Original Contributions of Research

The research discussed in this thesis makes a number of contributions to knowledge in the field of usability, usability testing, and the design and evaluation of VLE systems.

The first contribution is the results of a mapping study that obtained a clear view of current empirical work that relates to the usability of E-learning systems in higher education. It identified the methods currently used to evaluate platforms (such as standard questionnaires and interviews) and specific usability issues, for example, efficiency and effectiveness. The results show that adding other usability factors, such as navigation and attitude, to the standard usability attributes and using a combination of evaluation methods, such as focus groups and questionnaires, would be useful. The results also highlighted that few studies focused on the effectiveness of the evaluation techniques themselves (see Chapter Two). This work was presented at the 32nd International BCS Human–Computer Interaction Conference (Abuhlfaia & de Quincey, 2018).

The second contribution is the results of a large-scale usability evaluation study with 101 students which showed that there is disparity between the level of usability indicated by the SUS score and free text comments provided by respondents. This questions the validity of the SUS as the SUS score might not provide a full picture of how usable a system is when compared to user feedback. A number of recommendations to enhance the interface design and system usability have been provided, such as the need for staff training about how a module should be designed on a VLE with relevant and important materials. This work was published in the proceedings of the 3rd International Conference on Education and E-learning (ICEEL 2019) (Abuhlfaia & de Quincey, 2018) (see Chapter Four).

Another contribution is confirmation that the Technology Acceptance Model (TAM) could be improved for evaluating the ease of adoption of E-learning systems by adding usability and

learnability independently with PE. This was achieved by collecting the responses of a large number of students from Keele University (162 students). It was found that the usability and PE of the VLE directly affect the students' PU of using the VLE platform, and that learnability and perceived enjoyment have an impact on PEOU. However, usability and learnability do not have an effect on PE, which means that even if systems are not considered as usable, they are still perceived as enjoyable. (see Chapter Five).

The final contribution is the confirmation of previous findings by using a novel method for assessing usability both subjectively (via a short questionnaire based on three standard usability questions) (Lewis, 1994) and objectively (by asking users to complete a set of tasks and collecting the time and numbers of clicks needed to complete those tasks and comparing this to a baseline measure) based on actual use of a VLE in two sessions. The results showed that there is a mismatch between what people say about their experience and what they actually do when using a VLE, that is, participants' responses to the questionnaire indicated that they were satisfied with the usability of the system, which contradicts the results of the objective measures. (see Chapter Six).

The overarching contribution of this thesis is that by using several different approaches, the researchers have shown the usability evaluation techniques used currently have weaknesses and that researchers cannot rely on the use of one method alone to obtain a true picture of what users think and their experience of using a VLE.

1.5 Thesis Structure

The thesis is divided into eight chapters as outlined below. Chapter One presents the general background, purpose and aims of the research. This chapter also provides the research questions and a description of the structure of the thesis.

Chapter Two relates to a mapping study that identifies and classifies methods for assessing the usability of E-learning platforms, the platforms tested using these methods, and the issues identified using these methods.

Chapter Three describes the research methodology that was used during the study, including the research design, data collection methods and data analysis techniques.

Chapter Four discusses research methods that have been used previously to investigate whether a VLE is usable or not. This chapter then presents the results of a usability evaluation of a VLE platform and provides some recommendations to enhance the interface design and system usability.

Chapter Five presents the results of a study that attempted to extend the original TAM. The data collection method is described and the outcomes of multiple regression tests are reported. The chapter concludes by detailing the outcomes of a set of hypotheses tests and how they relate to the extended TAM.

Chapter Six describes an experiment used to assess the usability of the VLE used at Keele University using a combination of objective (by measuring users' interactions with the system) and subjective (standard usability questions) measures. The chapter concludes by reporting and comparing the results.

Chapter Seven discusses the findings of the different studies reported in this thesis, which are brought together and discussed in relation to the research questions and aims of this work, the research results, the contributions made by this thesis, and the implications of this study. This chapter also highlights the limitations of the research. Chapter Eight concludes this work and provides recommendations for researchers regarding how to assess the usability of VLEs in higher education, as well as suggestions for future work.

Chapter 2 Literature Review

This chapter provides a synthesis of empirical studies on the usability of E-learning in higher education in the form of a Mapping Study. First, a comprehensive investigation of empirical studies in the field of usability of E-learning from 2002 to 2016 was conducted to identify and classify the current state of knowledge in this area. An automatic search strategy was used to identify primary studies. A set of procedures was then adopted to validate the result of the mapping study, including verification of all the primary studies reported in previous reviews, and a team of two reviewers extracted data from a random sample of studies (Appendix B.2 Protocol Development Team). After applying the methodology, 61 research papers were identified as the final set of primary studies. These then form the basis of the review described in this chapter. The mapping study presented in Section 2.3 was published in 2018 in the Proceedings of the 32nd International BCS HCI Conference.

During the work on the reported research, a supplementary search of the related literature was performed and the mapping study was updated to 2019 which is presented in Section 2.4. This was done to ensure that all the relevant works published up to 2019 were identified. Finally, Section 2.5 summarises this chapter.

2.1 Introduction

A literature review (narrative review) is an objective, thorough summary and critical analysis of the relevant available research and non-research literature on the topic being studied (Hart, 1998). The systematic review is a methodology that aims to reliably allow researchers to collect evidence on a particular research topic area, or research question in their area of interest (Kitchenham et al., 2015). A systematic mapping study (SMS) is a form of systematic review which provides a summary of the knowledge in a particular area from previous papers and

articles without necessarily assessing the quality of each study (Kitchenham & Charters, 2007; Kitchenham et al., 2015). A SMS uses a more rigorous and well-defined approach to reviewing the literature in a specific subject area in question (Cruzes & Dybå, 2011). SMS also enables researchers to have broad views of a domain as well as to identify specific terms.

2.2 Background and Related Work

As the goal of this thesis is to investigate how best to assess the usability of Virtual Learning Environments (VLEs) this section gives an overview of related concepts and studies that have informed the mapping study and subsequent research.

2.2.1 E-learning Platforms

The following section outlines some of the more common E-learning platforms (not including bespoke platforms made by universities to meet their particular needs (Jain, 2015)).

2.2.1.1 Blackboard

Matthew Pittinsky and Michael Chasen, introduced Blackboard in 1997. Blackboard is a VLE (Logan & Neumann, 2010), where students are able to access course information (often in secured areas) and download and upload course materials and homework (Conrad, 2016). It can also be used to improve the efficiency of communication between learners and their institution. It supports a number of additional learning activities including conveying daily messages, tasks, course content, chat rooms, assignments, quizzes, exams, and grades (Eldridge, 2014).

2.2.1.2 Modular Object-Oriented Dynamic Learning Environment (Moodle)

The Moodle platform is used widely all over the world by institutes, universities, companies and independent educators (Al-Ajlan & Zedan, 2008). It has been used by more than 94 million users in 233 countries (Moodle.org, 2018). Moodle was originally created by Martin

Dougiamas in Australia in 1999, Fuentes, Ramírez-Gómez, García, & Ayuga, 2012) and is an open source product (Kumar, Gankotiya & Dutta, 2011).

2.2.1.3 Sakai

Sakai is a platform developed by a group of academic institutions and commercial organizations, working together to develop a Collaborative Learning Environment (Aggarwal, Adlakha, & Ross, 2012). Sakai was released in 2005 and is currently on version 12.0, which was released in March 2018. Similar to Moodle, Sakai is an open source platform and has been used within E-learning by over 350 institutions and by 4 million learners around the world (Sakaiproject.org, 2018). However, to be able to modify the user-interface of Sakai you need to have relevant programming skills in this field (Chauhan et al., 2015).

2.2.2 Usability

Nielsen (1993); International Standards Organization(ISO), (1998). were one of the first people to consider the usability of interactive systems such as web applications. They defined Usability to be the ease with which the functions of a system can be used effectively and without barriers, and defined six factors of Usability; Learnability, Efficiency Memorability, Errors, Satisfaction, and Effectiveness (Nielsen, 1993; ISO, 1998). Learnability reflects how easy it is for a new user to understand how to use a system to perform required tasks, and how quickly a user can become skilled in the use of a system (Nielsen, 1993). Efficiency is the ability to use a system to perform specific tasks with minimal effort (Nielsen, 1993; ISO, 1998). Memorability is the ability both to recall how to use a system to perform difficult tasks after a period of non-use, and to activate infrequently used functions. In the context of usability, Errors relates to using a system with minimal incorrect actions (such as inappropriate function calls or unnecessary or incorrect keyboard clicks) while performing a required task; if the rate of error is low and the users can recover from errors easily, the system is usable (Nielsen, 1993).

Satisfaction refers to how pleasant and attractive the user finds the system (Nielsen, 1993; ISO, 1998). Effectiveness is about the user achieving a specific goal and completing it accurately (Nielsen, 1993; ISO, 1998). Perceived Enjoyment (PE) is defined as "the extent to which the activity of using the technology is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated" (Davis, Bagozzi & Warshaw, 1992). According to Teo & Lim (1997) PE means that users would discover activities that bring pleasure and enjoyment.

2.2.3 Usability and E-learning

Usability plays an important role in an E-learning platforms' success as end users may spend a long time becoming familiar with functionality because it is not usable instead of studying the content of the module (Costabile et al., 2005). However, the usability of online learning platforms is a big challenge that designers have faced (Ardito et al., 2004), and has been shown to have a significant impact on learning (Plata & Alado, 2015).

There is a need therefore to evaluate usability issues to confirm factors such as the PE of users and the design and acceptance of new services and systems (Lesemann, Woletz, & Koerber, 2007; Granić & Ćukušić, 2011). This is corroborated in a systematic review conducted by de Leeuw et al. (2019), who argued that evaluation of E-learning design needs to be performed on the systems, not only on learning outcomes.

The following studies have investigated the usability of E-learning platforms and are summarised below.

Koohang, Paliszkiewicz and Nord (2015) evaluated the predictors of success in E-learning courseware usability design. They conducted a survey to evaluate the efficiency, student satisfaction, learnability and flexibility of an E-learning system along with general student attitudes towards learning management systems (LMS). The result of their experiment

demonstrated implications for LMS material design, its PEOU and how this affects the learning experience for students.

A study conducted by Elkaseh, Wong, and Fung (2016) explored the use of social media in education at universities. They argued that there is a need to explore the factors that can influence the initial use of social networks as an online learning tool. They tested the Perceived Usefulness (PU) and PEOU of using social networks and the VLE through questionnaires and interviews. It was found that PU and PEOU were the main aspects when accepting the use of social networks for distance learning.

Harrati, Bouchrika, Tari, and Ladjailia, (2016) explored the factors which affect Moodle platforms used by university lecturers. They investigated user satisfaction by using the System Usability Scale (SUS) questionnaire with 50 users that included university professors, lecturers and assistant lecturers. The result reveals that the SUS score is not adequate on its own to assess use and satisfaction of an E-learning platform over an extended period of time (Harrati et al., 2016). Harrati et al. (2016) recommended that more focus was needed on the usability factors of memorability and learnability and their relationship with PEOU over time.

A study conducted by Olanrewaju and Omiola (2018) investigated E-learning technologies used at the Federal University South-South Geo-Political Zone, Nigeria for its learning activities, based on age and gender, using a survey. The study showed average level of use of E-learning techniques by university students. It found that age is an indicator for E-learning tools' usability, whereas gender does not seem to affect their usability.

Batmetan, Mintjelungan, Manggopa, Kilis, & Kembuan's (2019) study aimed to measure the PU of VLE application in higher education using the TAM to determine the level of acceptance of the university's academic information system. A questionnaire was used to collect the data.

The outcomes of the study recommend the integration of adaptive features based on the user's requirements.

The study conducted by Maboe, Eloff and Schoeman (2018) at the open distance E-learning (ODeL) institution explored how usability related to the time of task completion. The authors recommended that the efficiency of the ODeL institution should be enhanced. They used eye tracking and observation as methods and found that users found it difficult to use the system without support. For example, users were not familiar with the text zoom option on the website, and users struggled to access the myUnisa link from the website. Some participants forgot their passwords and it was not easy to find the link to change passwords. Participants took a long time to discover certain links from the website. However, the participants in this study were students with disabilities, which may affect their use of the system as they potentially need more support.

Although in the last few decades several studies relating to the usability of E-learning platforms have been published, few reviews have evaluated and synthesised this information. Therefore, there is a need for a SMS to understand the current knowledge available. The following section describes the SMS in detail.

2.3 A Systematic Mapping Study of usability of the E-learning in higher education

2.3.1 Introduction

The SMS is organised as the following; Section 2.3.2 describes related platforms and reviews and section 2.3.4 outlines the methodology for the mapping study, including the search method and inclusion/exclusion criteria. Section 2.3.5 presents the results and sections 2.3.6 and 2.3.7 discuss the limitations and conclusions of this work.

2.3.2 Related Work

There have been two previous SMSs and several more general reviews in the area of the usability of E-learning platforms. However, the two previous studies have different aims to the study described in this chapter, which are outlined in the following section.

An SMS was performed by Nakamura et al. (2017) on the usability and user experience (UX) of LMS. This review aimed to analyse all studies that focused on LMS usability and UX evaluation techniques covering learning factors, type, availability performing method, restriction and origin, published between January 2004 and August 2016. The results of this SMS revealed that there is a need to study the lack of specific feedback given to address some of the issues and that more research is needed in the area of LMS.

The following are some of the main differences between this chapter and Nakamura et al.'s SMS. Although the two studies have almost the same number of papers (62 and 61), due to a difference in the inclusion and exclusion criteria, we have included five papers that were excluded in their study and they included eight studies that we excluded. Nakamura et al.'s study included papers that are not related to higher education and included work related to mobile learning (which we have excluded). Moreover, the study in this chapter has used Wiley Online Library and Google Scholar, whereas Nakamura et al. used only two databases, Scopus and Engineering Village (due to having limited access to various online libraries). Finally, we have covered a longer time period, January 2002 to December 2016, as Nakamura et al. covered January 2004 to August 2016.

Bernerus and Zhang (2010), presented a literature review (systematic review) based on the York methodology (Centre for Reviews & Dissemination, 2009) conducted by Bernerus and Zhang (2010) investigated usability evaluation methods (UEMs) for E-learning platforms, covering papers published between 2000 and 2010. They analysed relevant papers to determine

how pedagogical aspects and criteria were treated when usability evaluations were performed. They then presented a summary of all the UEMs from their included studies and factors related to E-learning. However, some common evaluation methods were not found in the 27 papers they included, e.g. focus groups, interviews, and log file analysis. This study summarised four important pedagogical usability factors: designing the content for learning, assessments, user's motivation to learn, and authoring supportive tools. Furthermore, they found that some studies were not fully aware of the importance of pedagogical aspects in usability (as opposed to general usability). However, their focus was limited to evaluation methods and limited by the lack of access to the full text of some articles. Moreover, the pedagogical usability factors summarised were based on their knowledge and what they had learnt from the case studies found. They admit that there may be other studies and usability factors that they have not considered (Bernerus & Zhang, 2010).

Freire, Arezes and Campos (2012), presented a literature review about the relationship between ergonomics and usability in E-learning covering the last 30 years. There are no details regarding whether the research was conducted in a systematic or narrative way. The analysis of this review's results enabled the authors to identify three differences among the UEMs used dependent on whether the system's performance, the user's performance or the dialogue between users and systems was being evaluated. The majority of methods that were used to test E-learning's usability were the same as those used for general systems, i.e. not specialist methods. This study contained a variety of points of view, as it included researchers from different scientific areas, such as Ergonomics, Computer Science, and Education. The researchers' conclusion was that the most important point is knowing how to combine the most relevant methods for each type of evaluation and type of stakeholder.

Plantak, Vukovac, Kirinic and Klicek (2010), the aim of their review was to identify a set of criteria for choosing appropriate methods to test the usability of online learning platforms. In addition to analysing current UEMs for E-learning platforms, they compared UEMs for distance learning. The conclusion of this review was that factors relating to effectiveness, time, ease of application, cost and efficiency can affect the decision regarding which usability testing method to use on E-learning platforms (Ssemugabi & de Villers, 2007b). The authors also found that instructions for the methods are lacking and that more information would be needed if the methods were to be adopted by other researchers. However, this review only covered a period up to 2010.

Ssemugabi and de Villiers (2007b), The aim of this study was to compare the results of two evaluation methods on the Info3Net system: the UEMs and heuristic evaluation. Ssemugabi and de Villiers (2007b) concluded that the results that were gathered using Heuristic Evaluation were similar to the result that was collected using a survey. However, more problems were identified by the four expert evaluators than the 61 students. Moreover, the Heuristic Evaluation conducted by the experts showed that it seemed to be an adequate and appropriate method to evaluate the E-learning systems.

Several reviews concerning the usability of E-learning have therefore been conducted. However, the mapping study described in this chapter has a different focus and set of research questions as well as different inclusion and exclusion criteria and is based on a systematic, reproducible method.

2.3.4 Research Method

This SMS has been conducted in line with the guidelines provided by Kitchenham et al. (2015), with the main stages shown in Figure 2.1. This section outlines the protocol of our SMS, including the research questions used to frame the study; the search strategy, e.g. which search

strings, databases, and inclusion and exclusion criteria were used; and the rules for extracting data and classifying primary studies.

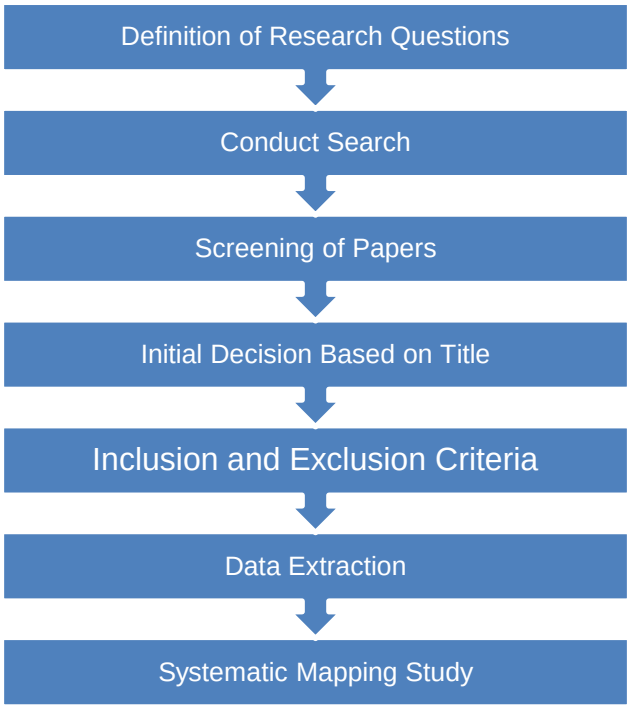

Figure 2.1: The Mapping Study Process

2.3.4.1 Research Questions (RQ)

The following research questions were formulated to explore the areas of usability that contribute to the effectiveness and success of E-learning among students, staff and lecturers in universities:

RQ1. What are the main attributes that have been used to assess the usability of E-learning platforms?

RQ2. Which usability issues have been identified in E-learning platforms?

RQ3. What methods/techniques are used to evaluate the usability of E-learning platforms?

RQ4. Which E-learning platform(s) has been evaluated?

RQ5. What was the level of study of the sample used in each paper?

RQ6. Which data analysis methods have been used?

RQ7. What data analysis tools have been used?

2.3.4.2 Search strategy

The search strategy aims to identify the most relevant literature related to the study area, focusing on research within articles, papers and journals Kitchenham and Charters (2007). The construction of the search strings followed the steps described by Brereton Kitchenham, Budgen, Turner, and Khalil (2007) and Kitchenham et al. (2015).

1. Identify major terms and synonyms by terms that are used in the research questions.
2. Identify different spellings and synonyms for major terms.
3. Use the Boolean operator "OR" to link alternative spellings and synonyms.
4. Use the Boolean operator "AND" to link major terms.

This resulted in the following keywords used in this search: (“Usability” OR “Usable” OR “ease of use” OR “user experience”) AND (“E-learning” OR “Distance learning” OR “Distance education” OR “Elearning” OR “electronic learning”).

The digital libraries used were the Institute of Electrical and Electronics Engineers (IEEE) Xplore Digital Library, Association for Computing Machinery (ACM) Digital Library, Google Scholar (search engine), Wiley Online Library, and ScienceDirect.

The search was limited to the period January 2002 to December 2016. The main reason for this was that E-learning platforms have been consistently updated and therefore versions before 2002 would not be representative of the current state of the art in the area. Moreover, the evolution of online technologies has had a significant effect on the delivery methods for E-learning courses, which again makes studies before 2002 less relevant.

To evaluate the validity of the search strings, ten key papers were identified from the relevant literature. An initial pilot search was then undertaken using the proposed search strings to test

whether these key papers would be returned in the results. The search strings were then adjusted depend on the results and each database's particular search criteria.

2.3.4.3 Search process

The full search strings were then inputted into each of the chosen digital libraries. All papers were downloaded based on their titles at this stage. The details of all the returned papers were then imported into the Mendeley software, helping the researcher to remove all instances of duplicate papers from different digital libraries. Next, the inclusion and exclusion criteria outlined in the following section were applied. This is where the papers were successively screened based on their relevance for the current review.

2.3.4.4 Inclusion and exclusion criteria

We carried out an initial selection process by applying the criteria to the title of all downloaded papers. If it was not clear whether the paper complied with an inclusion or exclusion criteria, it was included for further screening, which involved reading the abstract for each study and if needed, the introduction and conclusions. In some cases, it was necessary to read the full text to decide whether the paper was to be included or not. The full details are in Tables 2.1 and 2.2.

Table 2.1: Inclusion Criteria

No	Inclusion
1	Papers published between January 2002 and December 2016.
2	Written in the English language.
3	Peer-reviewed literature (conference proceedings and journal articles).
4	Paper which includes a description of evaluation about the usability of E-learning and has a clear method.
5	Combine users if the platforms were in Higher Education.
6	Papers presenting usability attributes other usability problems.

Table 2.2: Exclusion Criteria

No	Exclusion
1	Duplicate papers from the same study in different databases.
2	Publications not written in English.
3	Publications not directly related to our topic.
4	Where the data analysis process is not presented.
5	Publications related to the evaluation of materials.
6	Non-reviewed literature.
7	Study sample, which concerned about disabled users.

2.3.4.5 Data extraction strategy

This section outlines the collection of data from each of the included papers. A spreadsheet was created to store the extracted information from each of the included studies with each row representing one article, enabling further comparison and analysis. Meta-data was collected from each paper, such as the title of the paper, the authors, publication year, place of publication, and abstract (see Table 2.3). To achieve the objectives of this SMS, more specific data, for instance, the usability attributes considered (based on those specified by Nielsen (1993) and the ISO (1998), the method used, and the sample size, was needed to answer the research questions.

Table 2.3: Data Extraction

Code	Field /Data	Related Research Question
D1	Paper ID	Documentation
D2	Title of publication	Documentation
D3	Abstract and bibliography reference	Documentation
D4	Author Name(s)	Documentation
D5	Academic departments authors are affiliated with.	Documentation
D6	Publication source	Documentation
D7	Year of publication	Documentation
D8	Type of publication	Documentation
D9	E-learning platforms tested	RQ 4
D10	Aims and objectives	Documentation

D11	Research question(s) and/or hypothesis stated	Documentation
D12	Usability attributes used for assessment	RQ 1
D13	Name of the evaluation methods used.	RQ 3
D14	Number of participants	Documentation
D15	Participants in the study	Documentation
D16	Level of Education	RQ 5
D17	Tasks participants given	Documentation
D18	Usability problems found	RQ 2
D19	Data analysis tools used	RQ 6
D20	Data analysis methods used	RQ 7
D21	Conclusion and recommendations	Documentation

2.3.4.6 Validation

To validate the inclusion and exclusion process, two researchers (author and PhD Supervisor) cross-checked 22 articles and agreed that all of them met the exclusion criteria.

To validate the data extraction process, the protocol was piloted with the author and PhD Supervisor and an expert in the SMS method (see Appendix B.1, for the various iterations as the protocol was developed), who compared data extraction results across ten papers until a suitable level of agreement was met.

We then extracted the data for the 61 publications included in the study. To be fully satisfied that the information gathered was accurate, all included papers were read in full at this stage.

2.3.5 Results and Analysis

A total of 7,767 hits resulted from searches using the specified search strings on Google Scholar and the chosen databases, Association for Computing Machinery (ACM) Digital Library, Wiley Online Library, Institute of Electrical and Electronics Engineers (IEEE) Xplore, and ScienceDirect. The methodology described in section 3 was then followed with 199 papers downloaded from Google Scholar and the chosen libraries based on the titles of the publications found. A secondary selection was then made based on reading the abstracts, introductions and conclusions and applying the inclusion and exclusion criteria. This resulted in 53 failing to

meet the inclusion criteria and 146 remaining papers that needed to be read in full (and the inclusion and exclusion criteria applied). Following this process, a total of 61 articles were included (each article in the list has been assigned a reference number, e.g. "Ref P(1)") in the study (32 conferences papers and 29 journal articles, see Figure 2.2 shows the distribution of papers over years and the place of publication). The following table shows the number of papers found and included from each of the chosen libraries. The majority of the papers were downloaded from Google Scholar and only three papers were from Wiley Online Library.

Table 2.4: The numbers of searches found from the chosen libraries between 2002 and 2016

Digital Libraries	First Result Showed between (2002 and 2016)	Downloaded Papers	Included Papers	Excluded Papers
Google	193	128	31	97
ScienceDirect	256	16	11	5
IEEE	2,932	32	10	22
ACM	3,861	12	6	6
Wiley	525	11	3	8
Total numbers	7,767	199	61	138

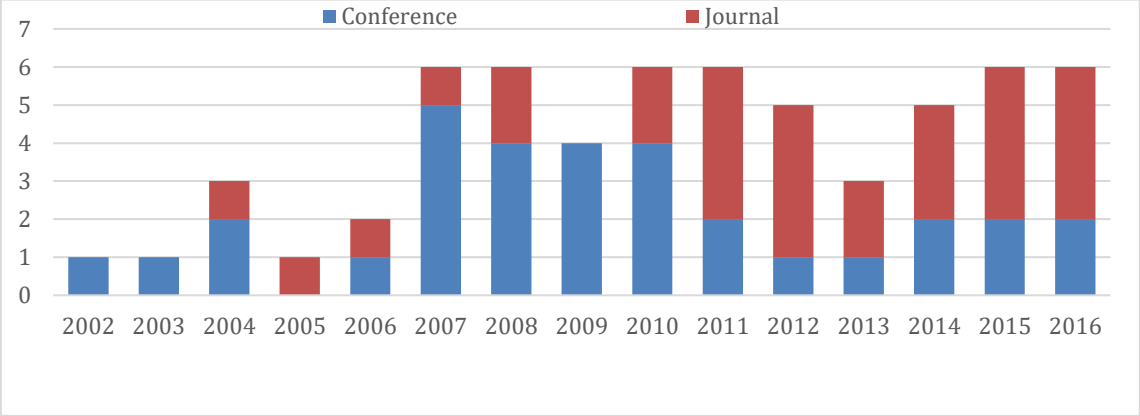

Figure 2.2: The distribution of papers over years

The following section reviews the primary results of the mapping study as well as the potential limitations. It provides the answer for each research question.

Results for RQ1 "What are the main attributes that have been used to assess the usability of E-learning platforms?". Table 2.5 illustrates the main usability attributes that have been explored by the primary studies. Effectiveness was the main attribute that has been investigated with 23 studies, followed by satisfaction (19), then efficiency (17). However, there was less focus on learnability and memorability, with 14 and 8 papers respectively. Perceived ease of use was explored in 14 studies and perceived usefulness in 11 papers. However, 12 papers did not specify which usability problems they studied.

We found that there are more papers focusing on effectiveness and satisfaction when evaluating E-learning systems. However, only a few papers considered error and memorability, highlighting the potential need for more work in this area.

Table 2.5: The usability attributes used for assessment

Usability attributes used for assessment	**Paper's Reference No.**	**No. of Papers**
Effectiveness	P1, P3, P6, P8, P11, P24, P26, P28, P33, P37, P41, P42, P44, P45, P48, P50, P52, P54, P55, P58, P59, P60, P61.	23
Satisfaction	P3, P7, P11, P15, P18, P21, P23, P26, P27, P31, P39, P41, P42, P45, P52, P54, P57, P58, P59.	19
Efficiency	P6, P7, P9, P13, P18, P26, P32, P42, P44, P45, P51, P52, P55, P56, P58, P59, P60.	17
Perceived ease of use	P3, P10, P15, P17, P21, P25, P27, P30, P31, P34, P36, P43, P47, P54,	14
Learnability	P1, P7, P8, P9, P13, P16, P20, P22, P32, P37, P39, P56, P61.	13
Not specific just usability issues	P5, P12, P14, P20, P24, P29, P31, P35, P38, P40, P46, P48.	12
Perceived usefulness	P3, P15, P17, P19, P21, P25, P27, P34, P43, P47, P54.	11
Memorability	P3, P4, P7, P32, P39, P41, P54, P61.	8
Error	P39.	1

Results for RQ2. "Which usability issues that have been identified in E-learning platforms?". Although Nielsen and the International Organization for Standardization (ISO) identified six main usability attributes (used in RQ1), there are other, more specific usability problems that affect the UX on E-learning platforms, which are also useful to classify. Table 2.6 shows a number of common usability problems that have been identified. Information quality was the most common problem found with eight studies, followed by attitude to use the system (7) and navigation (6). Helpfulness was found in four studies. However, 22 of the 61 papers did not specify which usability problems they encountered.

Table 2.6: The Usability issues that have been identified in E-learning platforms

Particular usability problems	**Paper's Reference No.**	**No. of Papers**
Not specified (general usability issues)"	P2, P4, P5, P6, P8, P14, P17, P18, P21, P24, P26, P28, P32, P34, P39, P41, P44, P45 ,50, P51, P52, P59.	22
Information quality	P19, P10, P27, P29, P31, P36, P47, P57.	8
Attitude	P3, P15, P20, P33, P37, P42, P54.	7
Navigation	P1, P10, P16, P25, P49, P54.	6
Helpfulness	P7, P9, P13, P56.	4
Control	9, 13, 56.	3
Flexibility	P37, P61.	2
Reliability	P37, P61.	2
User interface	P10.	1
Colour	P29.	1

Results for RQ3 "What are the methods/techniques used to evaluate the usability of E-learning platforms?". Table 2.7 below shows the usability evaluation/testing methods that were used in the included papers. A questionnaire was the main method used in 50 studies, followed by interviews (12) and observation (9). Focus groups were used in five studies and think aloud in six studies. Heuristic Evaluation was used in three papers and eye tracking in two.

Although a questionnaire was the main overall method used, 16 studies combined two methods or more, e.g. interview and observation. Specific types of questionnaire included the System Usability Scale (SUS), the Software Usability Measurement Inventory (SUMI), and the web-based learning and usability questionnaire (WLUQ). However, a number of studies did not give details about the type of questionnaire or questions they used, something that would be useful for future studies.

Table 2.7: The name of evaluation methods used

Methods used	Paper's Reference No.	No. of Papers
Questionnaire	P2, P3, P4 P5, P7, P8, P9, P11, P12, P13, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25, P26, P27, P28, P29, P30, P31, P33, P34, P35, P36, P37, P38, P39, P40, P41 P43, P44, P45, P46, P47, P48, P50, P53, P54 P56, P57, P58, P60, P61.	50
Interviewing	P1, P6, P10, P16, P22, P32, P34, P43, P46, P50, P55, P60.	12
Observation	P1, P9, P14, P32, P38, P39, P43, P46, P55.	9
Thinking Aloud	P6, P16, P32, P42, P43, P55.	6
Focus Group interview	P2, P31, P50, P51, P59.	5
Heuristic Evaluation	P2, P49, P53.	3
Eye Tracking	P1, P46.	2
Empirical analysis.	P11.	1
Audio Recording	P43.	1
Group Task Analysis	P52.	1
Mental rotations test (MRT)	P38.	1
Screen Recording	P46.	1

The table below shows a breakdown of the types of questionnaire that were used. SUS was used in seven studies, SUMI was used in four studies, and each of the other questionnaires was used in one study.

Table 2.8: The types of questionnaire used

Usability testing methods used	Paper's Reference No.	No. of Papers
SUS	P3, P12, P23, P26, P41, P45, P48,	7
SUMI	P8, P9, P13, P56.	4
Questionnaire for User Interaction Satisfaction short form	p46	1
Bill Gillham Questionnaire	p2	1
WLUQ	P19	1
Computer System Usability Questionnaire	p47	1
User Experience Questionnaire	P60	1

Results for RQ4 "Which E-learning platform(s) has been evaluated?". Table 2.9 shows that bespoke E-learning systems were evaluated in 20 papers and that the term LMS was used to describe platforms in 13 studies. Moodle was used in 12 studies; however, it is worth noting that some studies used both LMS and Moodle (studies 21, 50 and 51). The generic terms VLEs (7), web-based platforms and course management system (CMS) were used in three studies. However, 17 studies did not mention which platform they tested.

Table 2.9: The E-learning platforms tested

Platforms tested	Paper's Reference No.	No. of Papers
E-learning system	P1, P2, P9, P10, P12, P20, P21, P28, P30, P31, P32, P37, P38, P47, P48, P49, P50, P52, P56, P61.	20
Not specified	P6, P8, P16, P25, P28, P30, P33, P34, P39, P40, P41, P42, P46, P51, P55, P57, P59.	17
LMS	P5, P11, P14, P18, P22, P24, P29, P35, P36, P43, P53, P54, P60.	13
Moodle	P4, P5, P7, P13, P22, P23, P26, P36, P43, P54, P58, P60.	12
VLE	P3, P4, P5, P27, P44, P45, P58.	7
CMS	P13, P19, P50.	3
Web-based	P7, P18, P24.	3
Webinar	P17.	1

Results for RQ5 "What was the level of study of the sample used in each paper?". The table below classifies the participants in the study based on their level of study. The users in 27 papers were undergraduate students, followed by master's students with 14, PhD students with six, expert users with three, and administrators with two.

Many studies emphasise that the participants' level of education may affect the usability of the E-learning platforms, so it is concerning that 23 papers did not mention the level of study of respondents. Overall, undergraduate students were the main users to test the systems, with very few studies targeting expert users and administrative staff.

Table 2.10: The level of education of users

Users level of study	**Paper's Reference No.**	**No. of Papers**
Undergraduate	P1, P2, P3, P4, P9, P10, P12, P13, P20, P22, P23, P24, P31, P34, P35, P36, P37, P38, P39, P42, P43, P44, P48, P51, P54, P56, P61.	27
Not specified	P7, P8, P11, P14, P15, P16, P17, P18, P19, P25, P28, P29, P30, P32, P33, P40, P43, P46, P50, P53, P58, P59, P60,	23
Postgraduate Taught	P2, P5, P6, P21, P22, P23, P27, P39, P41, P45, P47, P52, P55, P57.	14
Lecture	P2, P22, P26, P28, P34, P43, P51.	7
Ph.D.	P2, P22, P23, P39, P41, P49.	6
Expert users	P2, P23, P43.	3
Administrations	P43, P51.	2

Results for RQ6 "Which data analysis methods have been used?". The table below shows software that has been used to analyse the results from the usability evaluations/tests, such as Statistical Package for Social Sciences (SPSS) (9), Linear structural relations (LISREL) (2), and two other tools, Tobii Studio and QSR Nvivo, each of which was used in one study. However, the majority of papers did not indicate which software they used to analyse their data.

Table 2.11: The data analysis methods used

Data analysis tools used	**Paper's Reference No**	**No. of Papers**
SPSS	P14, P20, P21, P23, P28, P31, P34, P44, P46.	9
Tested using LISREL 8.50.	P15, P57.	2
Tobbi T60 named Tobii Studio.	P1.	1
QSR Nvivo software	P46.	1

Results for RQ7 "What data analysis tools have been used?". Table 2.12 shows the data analysis methods used. Of the 61 studies, 39 used descriptive analysis, followed by Cronbach's alpha coefficient with 16, and ANOVA test with eight. Moreover, Structural Equation Modeling (SEM) and Partial least square (PLS) tests were each used in three studies, a Chi-square statistical test and squared multiple correlation (SMC) were used in two studies, and finally, five studies used other tests. However, 14 studies did not provide information about the data analysis methods used.

Table 2.12: The data analysis tools used

Data analysis methods used	**Paper's Reference No.**	**No. of Papers**
Descriptive analyses	P1, P3, P4, P7, P10, P11, P13, P14, P17, P18, P19, P20, P21, P22, P23, P25, P27, P28, P29, P31, P34, P35, P36, P37, P39, P40, P41, P42, P43, P44, P45, P47, P48, P54, P56, P57, P58, P60, P61.	39
Cronbach-Alpha coefficient	P8, P11, P15, P21, P23, P26, P30, P33, P34, P35, P36, P39, P40, P57, P60, P61.	16
Not specified	P5, P6, P12, P16, P24, P32, P46, P49, P50, P51, P52, P53, P55, P59.	14
ANOVA	P9, P18, P19, P26, P35, P38, P44, P45.	8
Average Variance Extracted	P21, P27, P47, P54, P57.	5
PLS	P4, P21, P47, P54.	4
SEM	P4, P15, P27.	3

Chi-square statistical test	P15, P41.	2
SMC	P27, P58.	2

Interestingly, there were no papers that used any form of automated usability testing, which can often be applied in the early stages of usability testing.

2.3.6 Limitations

The limitations of this study relate to misclassification, publication bias, selection bias, and inexactness in data extraction. SMSs suffer from the common issue of publication bias, i.e. negative results may not be published or cited, and positive results may be published faster than negative results (Kitchenham et al., 2015).

Selection bias refers to the misrepresentation of statistical analysis due to criteria that have been used in the selection of published papers (Fernandez, Insfran, & Abrahão, 2011). To try to mitigate this threat, detailed inclusion/exclusion criteria were determined and validated by the researcher. A related issue is that during data extraction, it is possible that information is overlooked or misclassified by reviewers.

2.3.7 Conclusions and future work

This SMS aimed to answer seven research questions concerning the usability of E-learning in higher education. We have presented the current state of the art according to 61 papers containing primary studies. Although there are two similar previous SMSs in this area, they each have a different focus and research questions.

The findings of this study suggest that adding other usability factors, such as navigation and attitude to use VLEs, to the standard usability attributes and using a combination of evaluation methods, such as think aloud, focus groups and questionnaires, would be useful. There does seem to be a reliance on questionnaires and interviews, which have been shown to miss important types of knowledge such as tacit and semi-tacit (Rugg and Petre, 2007). Moreover,

some studies did not provide certain vital information, for example, the platform they tested, the participants' background, and the tools they used to analyse their data; As few studies focussed on the effectiveness of the evaluation techniques themselves and provided specific suggestions to resolve the problems identified.

This mapping study gives a clear idea of the usability of E-learning to guide future researchers in this area. We observed that few studies use more qualitative methods such as think aloud and focus groups, and that few have examined usability factors such as perceived usefulness, memorability, and error. In the previous paper by Harrati et al. (2016), they expressed the opinion that it is possible to investigate the usability factors of memorability and learnability, and their relationship with ease-of-use over time by analysing the participant's usage logs. Our mapping study has demonstrated that such an approach has not been used to date in primary studies (and is the approach then taken in Chapter six).

2.4 Supplementary Literature Update

Studies published from January 2002 to December 2016 were included in the mapping study described previously. For completeness, relevant studies published between January 2017 and December 2019 have also been identified via an additional search of the literature. The same electronic resources and search terms were used. Furthermore, the search strategy presented in Section 2.3.4.2 was fully repeated. Table 2.13, shows the additional 16 studies that were found.

2.4.1 Results and analysis

A total of 63 hits resulted from searches using the specified search strings on Google Scholar and the chosen databases, ACM Digital Library, Wiley Online Library, IEEE Xplore, and ScienceDirect. The methodology described in section 2.3.4 was then followed with 26 papers downloaded based on the titles of the publications found.

Table 2.13: The numbers of searches found from the chosen libraries between 2017 and 2019

Digital Libraries	First Result Showed between (2017 and 2019)	Downloaded Papers	Included Papers	Excluded Papers
Google	63	26	10	16
ACM	37	2	1	1
IEEE	49	9	4	5
ScienceDirect	23	2	1	1
Wiley	11	3	0	3
Total numbers	**183**	**41**	**16**	**26**

A total of 16 articles were then identified that met the inclusion criteria (10 conferences papers and 6 journal articles). The majority of the papers were found via Google Scholar, with the distribution over time being 5 papers in 2017, 3 in 2018 and 8 in 2019.

The following section reviews the results of the updated mapping study on January 2020, as well as the potential limitations. It provides an updated answer for each research question.

Results for RQ1. The main usability attributes that have been explored by the primary studies. Perceived usefulness was the main attribute that has been investigated with 6 studies, followed by learnability and perceived ease of use with 4 studies each. However, there was less focus on memorability and error (See Table 2.14).

Table 2.14: The usability attributes used for assessment

Usability attributes used for assessment	Paper's Reference No.	No. of Papers
Effectiveness	P62, P67.	2
Satisfaction	P62, P66, P74.	3
Efficiency	P62, P66, P69.	3
Perceived ease of use	P65, P67, P74, P76.	4
Learnability	P63, P66, P69, P73.	4
Not specific just usability issues	P64, P 68, P70, P72, P77.	5
Perceived usefulness	P62, P64, P65, P67, P74, P76.	6
Memorability	P66.	1

Error	P69.	1

Results for RQ2. Two of common usability problems that have been identified See table 2.15.

Table 2.15: The Usability issues that have been identified in E-learning platforms

Particular usability problems	**Paper's Reference No.**	**No. of Papers**
Information quality	P63	1
Attitude	P64	1
Navigation	P63, P77.	2
Intention to use	P64, P65	2
Reliability	P66	1

Results for RQ3. Table 2.16 below shows the usability evaluation/testing methods that were used in the included papers. As was the case in the main mapping study, the questionnaire was the main method used in 16 studies, followed by interviews (6). Although a questionnaire was the main overall method used, 15 studies combined two methods or more, e.g. interview. Specific types of questionnaire included the SUS in the majority of the studies.

Table 2.16: The name of evaluation methods used

Methods used	**Paper's Reference No.**	**No. of Papers**
Questionnaire	P62, P63, P64, P65, P66, P67, P68, P69, P70, P71, P72, P73, P74, P75, P76, P77.	16
Interviewing	P62, P64 , P66, P68, P70,P71,P75	7
Heuristic Evaluation	P68	1
Group Task Analysis	P69	1

Results for RQ4. E-learning systems were evaluated in 9 papers and that the term LMS was used to describe platforms in 6 studies.

Results for RQ6 and Results for RQ7. The software that has been used to analyse the results from the usability evaluations/tests, such as SPSS, SmartPLS and PLS-SEM used in one study. However, the majority of papers did not indicate which software they used to analyse their data

here as well, as they included only some descriptive analysis. The thematic analysis method was used in one study (P62 and P77).

In conclusion, interestingly there does seem to have been more work recently on the usability factor "Perceived usefulness" (which was one of the least studied factors pre-2016); while, there is still not much work on memorability and error. Although, mixed-method approaches have been used more frequently since 2016, questionnaires are still the dominant method.

2.5 Chapter Summary

The current state of the art was reported in this chapter in the form of a mapping study, in the area of usability of E-learning, focusing on the methods used to evaluate usability issues. The findings of this chapter addressed thesis objectives numbers 1 and 2 ("To identify the state-of-the-art in the area of evaluating the usability of VLEs used in HE" and "To evaluate the usability of a commonly used VLE in HE using standard methods"). The evidence gathered indicates that most studies use questionnaires as the main usability evaluation method and focus on usability factors such as Effectiveness, Satisfaction and Efficiency. The majority of papers are also missing important data such as the types of participant and the tools that were used to analyse the collected data. This has indicated that there is more research needed in the area of the usability of E-learning, looking into the methods used for evaluation and specific usability issues they find. This is the aim of Chapters Four and Five. Few previous studies have used mixed method approaches (in particular combining subjective e.g. questionnaires, and objective e.g. log data, methods) and there has been less focus on some usability factors such as learnability, memorability, and error. This is the focus of Chapter Six. The following chapter outlines the methodology used for these studies.

Chapter 3 Research Methodology

3.1 Introduction

This chapter contains details of the research methodology that has been employed in this thesis. Section 3.2 outlines the research design. Sections 3.3 and 3.4 describe the questionnaire and observation respectively. The statistical tools are outlined in Section 3.5, and then Section 3.6 explains the ethical approval process. Finally, Section 3.7 presents a summary of the chapter.

3.2 Research Design

Mixed methods were chosen for the studies in the following chapters as they provide the opportunity to gain a better understanding of the circumstances than would be possible using one method (Creswell & Clark, 2007). This includes both quantitative and qualitative methods as suggested by Johnson, Onwuegbuzie & Turner (2007), for example, by using questionnaires and observations (Dornyei, 2007, p.24). The use of varied techniques have been shown to be helpful in gaining an understanding of the investigated world and construct meaning (Bell, 1999; Patton, 2002) and were highlighted as a previous gap in the literature in the previous chapter.

3.3 Data collection methods

The following are some common usability data collection methods (identified from the Mapping Study described previously):

- A *questionnaire* is a method where participants are asked questions and their answers are recorded. This method has the advantage of being able to test the users' satisfaction

with a particular system (Nielsen, 1993). An example of a questionnaire is the System Usability Scale (SUS), which was developed by Brooke (1996).

- *Observation* is the simplest method in usability testing; the observer watches how people use the website, and the observer is able to take a very short summary or in some cases may record video during the test. It is recommended that the observer does not ask participants questions until the end of the testing (Nielsen, 1993).
- *Eye tracking* is a method in which the movement of the person's eye is measured. Therefore, the specialist recognises when the user is viewing at a particular time and when the eyes begin to move between two points. The record of the eye movement may offer an objective source of interface-evaluation data, so the designer will know the issues and the interface will improve (Poole & Ball, 2006).
- *Heuristic evaluation* is about watching the interface of a website and then summarising your views, for example, the things that you like and or dislike, after you have used the system for one or two hours (Nielsen, 1993). Heuristic evaluation is often used in usability engineering to identify the usability issues in the user-interface, with a typical number of users being three to five (Nielsen & Molich, 1990; Nielsen, 1993). Although using heuristic evaluation is inexpensive and does not require advance planning, it often identifies usability problems without providing direct suggestions for how to solve them (Nielsen & Molich, 1990). Therefore, this method does not usually generate insights in the evaluated design but only identifies general usability issues. Furthermore, some issues can be identified as a problem when they are not actually a problem for the end users (Nielsen & Molich, 1990) as the testing does not involve eliciting the users' opinion. As the focus of this research was to identify specific

usability issues from the perspective of the user, other usability evaluation methods were used.

- *Interviewing* is a flexible method where researchers ask several people questions at the same time in a face-to-face interactive meeting with natural language. In this method, the researcher can ask the respondents follow-on questions. Interviewing can also be conducted over the phone (Nielsen, 1993; Rugg & Petre, 2007).
- A focus group is where a number of people, usually between four and 15, come together in one place to talk over, or consider, particular research issues. To improve the understanding, open-ended question is often used (Stewart & Shamdasani, 2014).
- *Think aloud* is where the researcher asks target users to use an application and say out loud what they are currently thinking, that is, simply expressing their opinions as they are interacting with the user-interface during the test (Nielsen, 2012).

For the studies in this thesis, questionnaires and observation have been used in the following three studies and are therefore described in more detail in the following sections.

3.3.1 Questionnaire

Questionnaires include a number of questions that are prepared in advance, to which respondents are asked to give their personal answer. It is possible to hand out a questionnaire to a large number of users (Nielsen, 1993; Rugg & Petre, 2007). Palys and Atchison (1997) stated that the quantitative research approach is commonly used in social science studies, including education. Quantitative research can be used to identify the relationships and the effects between factors (Wiersma & Jurs, 2009). However, questionnaires can gather qualitative data if open ended questions are added or adding in a free-text response question (Bryman, 2006). The questionnaire is considered appropriate for theory testing and it is commonly used in non-experimental design (Song, 2010). A survey is applied to assess the

perception and attitudes of the users (Glatthorn & Joyner, 2005). There are a number of different types of questionnaire, for example, online and written questionnaires. Zaharias and Poylymenakou (2009) described questionnaires as a reliable method for testing VLE platforms, as they take less time and are not as costly as other methods. This was supported by the mapping study published by Abuhlfaia and de Quincey (2018), which stated that the questionnaire was the main method to assess E-learning platforms in higher education.

Several advantages of questionnaires are highlighted in the literature, for example, their ability to compare responses and their advantages in terms of bias. It is not an easy task to use other methods such as eye tracking with a large number of face-to-face participants; therefore, questionnaires can avoid this difficulty. There is another advantage of using a questionnaire: it improves the accuracy of the responses by allowing the respondents to think about their answers (Algahtani, 2011). As a result, the questionnaire is generally recognised as an effective method in terms of work, money and time (Gay & Airasian, 2000; Oppenheim, 2001; Cohen, Manion, & Morrison, 2004). However, the questionnaire must be accurately prepared with the necessary skills to avoid a lack of understanding and a poor return rate.

Specific questionnaires related to usability evaluation e.g. the SUS are discussed in more detail in Section 4.3.

3.3.1.1 Questionnaire reliability

Reliability is about the extent to which test results are conceptualised in quantitative research and free of measurement error. It contains two main forms: internal consistency and repeated measurement (Muijs, 2004). Several researchers recommended conducting a pilot study (Wellington, 2003; Alashari, 2007). Bell (1999) stated that in the pilot study, the collected data is important to verify that all instructions and questions are clear and it allows the researcher to delete all items that affect the data. If the level of Cronbach's alpha is more than 0.7, then

this confirms a high level of internal consistency of the measurements as suggested by Hair, Anderson, Tatham and Black (2010).

3.3.2 Observation

Using qualitative method sometimes does provide comprehensive, rich and deep information. Nielsen, (1993) states that observation is the simplest method in usability testing. During observation, the observer sees how people use a website or how they behave in a particular situation with almost no interaction from the observer (Nielsen, 1993). The observer is able to record and or take notes during the observation where possible (Nielsen, 1993). There are two types of observation (Rugg & Petre, 2007): direct observation, where the observer watches how the users perform with little interaction between the observer and the users, and indirect observation, where the observer does not ask about the primary activity and does not watch the activity itself, instead watching other things that the observer can use to gather information regarding the main activity. Indirect observation can be disclosed or undisclosed. Disclosed observation is where the users know that they are participating in an experiment (Rugg & Petre, 2007). In undisclosed observation, the users do not know that they are involved in the study, which creates a number of ethical issues (Rugg & Petre, 2007).

3.3.3 Conclusion

For the remaining studies in this thesis, both questionnaire and observation have been explored. From the SMS results in Chapter Two (See Table 2.7), questionnaires were the most common method that have been used between 2002 to 2019. However, questionnaires have been shown to miss important types of knowledge such as tacit and semi-tacit (Rugg & Petre, 2007). Therefore, using both subjective and objective methods can provide a better understanding and broader picture of how usable a system is (Fritz, Balhorn, Riek, Breil, & Dugas, 2012). Observation was selected as a method in this research because it is a simple

method used in usability testing and allows us to see how people use the VLE and how they behave in a particular situation with almost no interaction from the observer (Nielsen, 1993; Rugg & Petre, 2007). By using a combination of measurements (such as task completion times and the number of clicks taken when using the VLE) to check the actual use and a short questionnaire based on standard usability questions (Lewis, 1994) this hopefully gives a more complete pictures of the usability of a system. (see Chapter Six).

3.4 Data analysis techniques

The statistical tools that were used for the studies are described in the following sections**.**

3.4.1 Statistical Package for Social Science (SPSS)

SPSS was used as a tool to analyse the studies in Chapter 4 and Chapter 5 using the Cronbach's alpha coefficient, means, standard deviation tests of frequency, percentages, the correlation and coefficients to measure reliability and validity. These tests resulted in knowledge of the characteristics of the sample. After consultation with statisticians at Keele University, we decided to employ these measurement tools during the design phase of the questionnaire.

3.4.2 Thematic analysis

Thematic analysis is a technique used to analyse qualitative data by identifying them within data, usually applied to a set of texts (Braun & Clarke, 2006). It minimally systematises and defines the data set in rich detail. Researchers should learn the thematic analysis technique because it offers essential skills that can be valuable to conduct several further forms of qualitative analysis (Braun & Clarke, 2006). Thematic analysis contains six phases (see Table 3.1).

Table 3.1: Phases of thematic analysis (Braun & Clarke, 2006)

	Phases and their descriptions
1	Familiarising with the data: Transcribing data, reading and re-reading the data, noting down initial ideas
2	Generating initial codes: Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
3	Searching for themes: Collating codes into potential themes, gathering all data relevant to each potential theme
4	Reviewing themes: Checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic 'map' of the analysis
5	Defining and naming themes: Ongoing analysis to refine the specifics of each theme and the overall story the analysis tells, generating clear definitions and names for each theme
6	Producing the report: The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis

3.4.3 Snagit

Snagit is a screencasting tool that captures video display and audio output. It was used in the study described in Chapter 6 to record participants' interactions with the VLE (during set tasks) as a form of indirect observation.

3.5 Ethical approval

This study followed a model of social and ethical research, particularly the guidelines regarding ethical issues in educational research of Cohen et al. (2004). Consequently, official approval was obtained from the Ethical Review Panel at Keele University for the study described in chapter four and study in chapter five ethical approval Ref: ERP3123 and for the study described in chapter six (ERP2397), (see Appendix A.4). All participants agreed to participate and signed an informed consent form (see Appendix A.3 & Appendix A.7) and Information sheets in (Appendix A.2 & Appendix A.6), describing the research objectives and the methodology were sent to all the students.

3.6 Overall Methodology and Study Design

The following outlines the three main studies and which methods have been used in each of them (See Table 3.2):

1. Chapter Four: "Evaluating the Usability of an Electronic learning (E-learning) platform within higher education from a Student Perspective" has used a questionnaire (subjective close ended and open ended questions) combined with free text responses (qualitative) in order to address RQ1 and RQ2. The Capuano, Gaeta, Ritrovato, & Salerno (2014) calculation has been used to calculate the usability score.
2. Chapter Five: The Influence of Usability, Learnability and Perceived Enjoyment on Technology Acceptance has used a questionnaire (subjective) based on a combination of pre-existing measures and scales. This study has addressed RQ3, using SPSS to analyse the collected data.
3. Chapter Six: Usability evaluation of Virtual Learning Environments has combined subjective measures, in the form of a Lewis (1994) questionnaire, and objective/qualitative measures (time taken and number of clicks), elicited by a form of observation (screen recording). This addresses RQ4 and RQ5.

Table 3.2: The three studies and the methods used

Chapters	Questionnaire (Subjective)	Questionnaire (Subjective and objective)	Observation (Objective)
Chapter Four		*Questionnaire (Subjective)* *SUS + open ended question (free text)*	
Chapter Five	*Questionnire (Subjective)* *SUS + TAM model*		
Chapter Six	*Questionnire (Subjective)* Lewis (1994)		*Observation (Objective)* *Predfined tasks*

			Time needed and Numbers of Clicks

3.7 Chapter Summary

The research in this thesis employs two methods to collect data about the usability of the VLE; questionnaires given to student participants and then observation of them completing tasks. The instruments developed for these studies include questionnaire questions related to overall usability in the first study and then three of the selected usability aspects, namely learnability, efficiency and error in the second study, and usability, learnability and perceived enjoyment in the third study. Data analysis was conducted using SPSS for the quantitative aspects of the questionnaires, while thematic analysis was used for qualitative questions, following Braun and Clarke's (2006) method. . We then developed measures to evaluate usability, in Chapter Four this was an open ended question to the students asking if they have any more concerns regarding the usability of the VLE, and in Chapter Six, predefined tasks were completed by the students and the times and number of clicks needed to performed the tasks was calculated. The next chapter describes the first experiment that employs some of these methods to assess the usability of a VLE and explore their efficacy.

Chapter 4: Evaluating the Usability of an E-learning Platform within Higher Education from a Student Perspective

In this chapter, an investigation into the usability of a Virtual Learning Environment (VLE) platform in higher education is presented. The study evaluates a VLE used in a higher education setting and provides some recommendations to enhance the interface design, system usability, and subsequent learning performance. Quantitative and qualitative research methods were used in the form of a survey of 101 students recruited from all Schools at Keele University, to assess whether the system is usable or not (using the SUS), from which 27 free-text responses were obtained for thematic analysis. The findings of this chapter were presented as a full paper at the 3rd International Conference on Education and E-learning (Abuhlfaia & de Quincey, 2019).

4.1 Introduction

Electronic learning (E-learning) platforms have become an essential tool for educators and students, playing a vital role in learning and teaching (Ventayen et al., 2018). A number of studies have identified issues in existing E-learning systems though, for example, user interface issues, design, and navigation (Arshad et al., 2016; Alturki & Aldraiweesh, 2016; Tee et al., 2013; Vertesi et al., 2018). The usability of the VLE is also one of the key factors that determine whether the system will be accepted by users or not (Babić, 2012; Parsons, 2017). It is not a simple task though to evaluate the usability of VLE platforms because of the nature of the evaluation methods required (commonly requiring resource intensive user participation) and is therefore a relatively a new area of research (Arshad et al., 2016).

However, even though usability is a known issue, the problem remains as VLE platforms are still difficult to use (Abuhlfaia & de Quincey, 2018; de Leeuw et al., 2019). Therefore, the main motivation of this chapter in this thesis is to evaluate the usability of a commonly used VLE platform in higher education from the student perspective to identify common issues that students have when using it in order to make some recommendations for improvement. Beings as questionnaire is the most common method that has been used to perform usability evaluation (as shown in Chapter two Table 2.5) this also gives the opportunity to explore this method and identify potential strengths and weaknesses in its use.

The chapter is organised as follows: Section 4.2 describes the proposed methodology; Section 4.3 presents the questionnaire design; Section 4.4 presents the results; Section 4.5 presents the discussion; and finally, Section 4.6 presents the conclusions and makes recommendations for future work.

4.2 Research methodology

For this study, the VLE in use at Keele University (Blackboard) ("Blackboard | Education Technology & Services", 2019). Formed the usability testbed, a questionnaire based on the SUS (Brooke, 1996) with the addition of questions related to demographics, prior experience and concerns/suggestions was created and then hosted online via Google Forms. Google Forms was used as it helped to remove the weakness of a poor return rate as it indicated any missing answers to the respondents. For participant recruitment, an advertisement was displayed on the VLE for all the students at the University (see Appendix A.1). It included the questionnaire link and an information sheet, describing the research objectives and the methodology (see Appendix A.2), and could be completed at the respondent's convenience. The documents required for ethical approval were submitted to the Research Ethics Committee by the student

in consultation with the supervisor, including the application form, participant information sheet, consent form, copies of the questionnaire, and a copy of the promotional email. The Research Ethics Committee recommended amendments prior to approval which were addressed. In particular they raised an issue of providing a reward for participation (in the form of Amazon vouchers). Since the first study was anonymised, the committee advised that it would be better to remove this incentive to keep the project simple, anonymous and online. They felt that participants would be keen to take part regardless of the Amazon voucher incentive. Also, the ethics committee highlighted that some terms could be considered coercive and suggested that these terms should be rephrased, for example, changing *'will be required'* to submit online consent to *'will be asked'*, and required that a specific date or stage of withdrawal be set.

In addition, the ethics committee highlighted some anomalies between the questionnaire and the information on the form and participant information sheet, which were corrected.

To achieve the study objectives, we formulated the following research questions:

RQ1 Is the VLE usable from the students' perspective?

RQ2 What are common issues that students have when using the VLE?

RQ3 Are standard questionnaires an appropriate method for evaluating the usability of a VLE?

4.3 Questionnaire design

Part one of the questionnaire asked for demographic information e.g. age, gender, level of study, School, and to give an indication of their level of experience with the VLE details e.g. duration of study and the last time a student used the VLE. The second part was based on the SUS, a commonly used (see Chapter Two Table 2.8) "quick and dirty" tool to reliably measure ease of use (Brooke,1996) (see Appendix C.3 System evaluation). It contains ten

questions/items to measure usability: five items are positive (1, 3, 5, 7 and 9) and five items are negative (2, 4, 6, 8, 10). For each item, respondents are given five options to signify their level of agreement (from Strongly agree to Strongly disagree). It evaluates a wide variety of products and services, including hardware and software (Brooke,1996) and was therefore used to answer RQ1. In order to elicit common issues (to answer RQ2), once they had completed the 10 SUS questions, respondents were asked for other comments and suggestions regarding their experience with the VLE (qualitative data). The questionnaire was piloted with 15 participants to test the reliability and consistency and analysed using SPSS version 24. The participants for this pilot (and the full study) were undergraduate and postgraduate master's students from Keele University and appropriate amendments to the questionnaire design were then made (final design described above). For the purposes of analysis, the negative statements contained in the (SUS Q2, Q4 Q6, Q8 and Q10) were recoded before calculation. For the pilot the level of Cronbach's alpha was more than 0.7 , which confirmed the high level of the internal consistency of the measurements as suggested by Hair, Anderson, Tatham and Black (2010).

4.3.1 Profile of respondents

Demographic information (see Appendix C.1 Profiles of respondents) of 101 users was tabulated using descriptive frequency analysis (Table 4.1). It shows that the majority of respondents were undergraduate students aged 18-27, female and from the United Kingdom (UK).

Table 4.1: Profile of participants and their expertise

		Frequency	**Percentage**
Age (in years)	18–27	86	85.1
	28–37	10	9.9
	38–47	4	4.0
	48+	1	1.0
	Total	**101**	**100%**

Gender	Male	30	29.7
	Female	70	69.3
	Prefer not to say	1	1.0
	Total	**101**	**100%**
Level of Study	Undergraduate	80	79.2
	Postgraduate master's taught	21	20.8
	Total	**101**	**100%**
Area of Origin	UK	78	77.2
	EU	6	5.9
	International	17	16.8
	Total	**101**	**100%**
School Name (Major)	School of Health & Rehabilitation	3	3.0
	School of Medicine	8	7.9
	School of Nursing and Midwifery	5	5.0
	School of Pharmacy	14	13.9
	Keele Management School	5	5.0
	School of Humanities	7	6.9
	School of Law	2	2.0
	School of Politics, International Relations & Philosophy	7	6.9
	School of Social Science & Public Policy	6	5.9
	School of Computing & Mathematics	15	14.9
	Schools of Life Sciences	6	5.9
	School of Chemical & Physical Sciences	2	2.0
	School of Psychology	15	14.9
	School of Geographical Sciences, Geology and the Environment	6	5.9
	Total	**101**	**100%**

4.3.2 Experience and duration of study using the VLE

This section relates to the experience and time spent using the VLE. Part one of the questionnaire was used to determine the last time the respondent used the VLE, with three alternatives of 'less than one week ago', 'less than one month ago' and 'more than one month ago'. The demographic section also contained questions related to the duration of study at Keele University (less than one year, one to two years, or more than three years). The experience of using the VLE is useful to consider as this may affect the student's perception of

how learnable the system is (see Table 4.2) (see Appendix C.2 Profiles of respondents Experience and duration of study using the virtual learning environment).

Table 4.2: Experience and duration of study

		Frequency	**Percentage**
Last Time You Used the VLE	Less than one week	97	96.0
	Less than one week	4	4.0
	Total	101	100%
Duration of Study at Keele University	Less than one year	37	36.6
	One–two years	31	30.7
	Three or more years	33	32.7
	Total	101	100%

This shows that the students use the VLE regularly, and that there was a mixed 'duration of study' from one to three years. Demographic information was collected to determine the level of respondent representativeness in terms of age sex, and background across the university.

4.4 Results

4.4.1 Reliability of measurements main test

For the full set of results, we then conducted a reliability test of measurement using Cronbach's alpha (for the reliability analysis results, see Table 4.3). The level of Cronbach's alpha was more than 0.7, which confirmed the high level of the internal consistency of the measurements as suggested by Hair, et al. (2010).

Table 4.3: Test of system usability

No.	**Items**	**Cronbach's Alpha**
1	I think I would like to use the VLE frequently.	.891
2	I found the VLE unnecessarily complex.	.848
3	I thought the VLE was easy to use.	.852
4	I think that I would need assistance to be able to use the VLE.	.868
5	I found the various functions in the VLE well integrated.	.857

6	I thought there was too much inconsistency in the VLE.	.856
7	I would imagine that most people would learn to use the VLE very quickly.	.865
8	I found the VLE very cumbersome/awkward to use.	.847
9	I felt very confident using the VLE.	.853
10	I needed to learn a lot of things before I could get going with the VLE.	.859

4.4.2 Questionnaire results

4.5.2.1 Usability descriptive statistics

Figure 4.1 shows the results for the 5 positive SUS questions (1, 3, 5, 7 and 9) and Figure 4.2 the five negative questions (2, 4, 6, 8, 10). All 101 respondents completed all questions, confirming the involvement of the whole sample.

For the first item of usability (SUS1), which stated '*I think I would like to use the VLE frequently*', five participants strongly disagreed (5.0%), 3 disagreed (3.0%), 6 were neutral (5.9%), 39 agreed (38.6%), and 48 strongly agreed (47.5%). This shows that the majority of respondents (86.1%) agreed that the they would like to use the VLE frequently.

For the second item of usability, which stated '*I found the VLE unnecessarily complex*' (SUS2), 8 strongly disagreed (7.9%), 43 participants disagreed (42.6%), 19 were neutral (18.8%), 27 agreed (26.7%), and 4 strongly agreed (4.0%). Overall, the majority (51%) did not find the VLE unnecessarily complex.

Regarding the third item of usability (SUS3), which stated '*I thought the VLE was easy to use*', 1 participant strongly disagreed (1.0%), 19 disagreed (18.8%), 21 were neutral (20.8%), 54 agreed (53.5%), 6 strongly agreed (5.9%). 60% of participants therefore thought the VLE was easy to use.

Overall, for the fourth item of usability, which stated '*I think that I would need assistance to be able to use the VLE'* (SUS4), 30 strongly disagreed (29.7%), 44 disagreed (43.6%), 9 were

neutral (8.9%), 15 participants agreed (14.9%), and 3 strongly agreed (3.0%). 73% of participants therefore felt that they did not need assistance to be able to use the VLE.

The results for the fifth item of usability (SUS5), which stated *'I found the various functions in the VLE well integrated'*, showed that 3 participants strongly disagreed (3.0%), 23 disagreed (22.8%), 25 were neutral (24.8%), 42 agreed (41.6%), and 8 strongly agreed (7.9%). This shows that only 50% of respondents felt that the various functions were well integrated.

The sixth item of usability (SUS6) stated *'I thought there was too much inconsistency in the VLE'*. The results for this item show that 7 strongly disagreed (6.9%) 40 disagreed (39.6%), 25 were neutral (24.8%), 26 participants agreed (25.7%), and 3 strongly agreed (3.0%). Therefore, the results for this item are mixed with less than half (47%) disagreeing that there was too much inconsistency.

SUS7 stated *'I would imagine that most people would learn to use the VLE very quickly'*. For this item, 4 participants strongly disagreed (4.0%), 19 disagreed (18.8%), 14 were neutral (13.9%), 50 agreed (49.5%), and 14 strongly agreed (13.9%). This shows that the majority (54%) agreed that the VLE would be quick to learn.

SUS8 stated *'I found the VLE very cumbersome/awkward to use'*. The analysis reveals that 10 strongly disagreed (9.9%), 46 disagreed (45.5%), 16 were neutral (15.8%), 27 agreed (26.7%), and 2 participants strongly agreed (2.0%). The majority of the participants therefore disagreed that they found the VLE awkward to use.

SUS9 stated *'I felt very confident using the VLE'*. The analysis shows that 1 strongly disagreed (1.0%), 15 participants disagreed (14.9%), 19 were neutral (18.8%), 52 agreed (51.5%), 14 strongly agreed (13.9%). 65% of the participants therefore stated they were confident using the VLE.

Finally, SUS10 stated *'I needed to learn a lot of things before I could get going with the VLE'*. The results show that 11 strongly disagreed (10.9%), 43 disagreed (42.6%), 21 were neutral (20.8%), 19 participants agreed (18.8%), and 7 strongly agreed (6.9%). Around half of the participants disagreed that they needed to learn a lot of things before they could use the VLE.

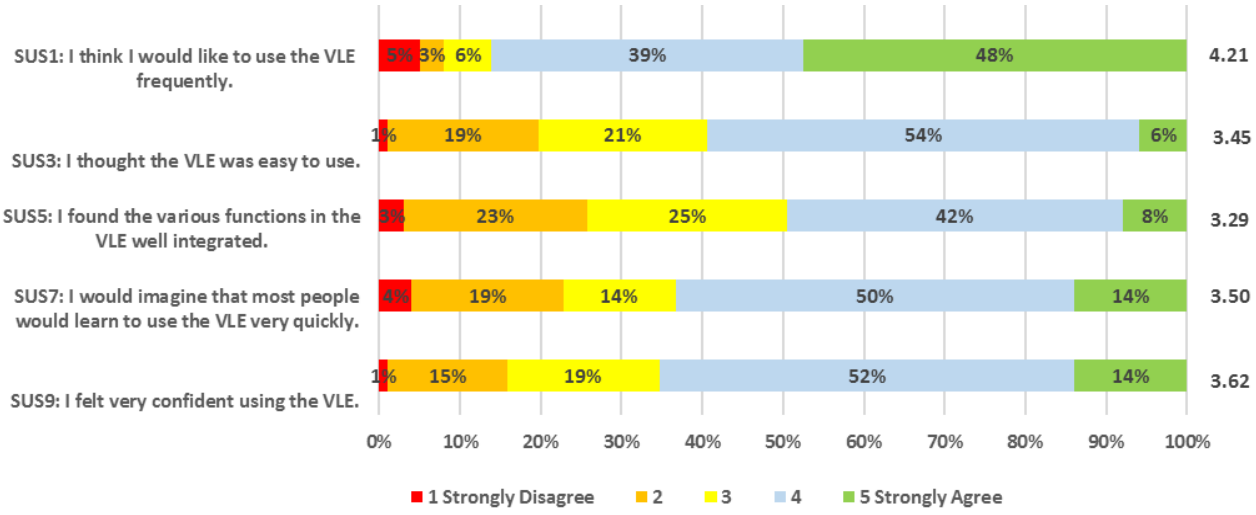

Figure 4.1: System Usability Score for the VLE: Positive items

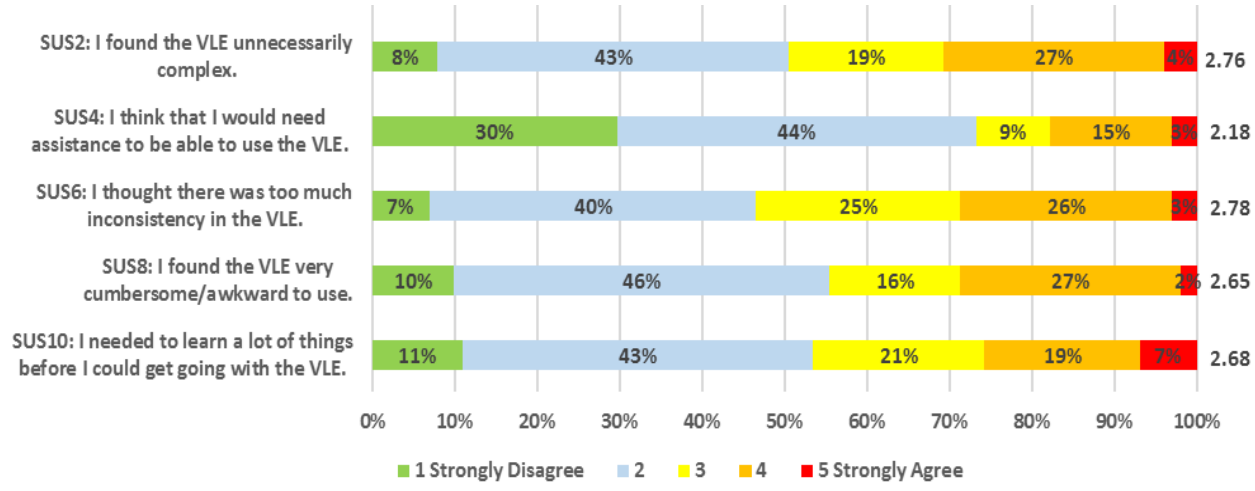

Figure 4.2: System Usability Score for the VLE: Negative items

4.5.2.2 Overall usability score

In total, 101 respondents measured ten items of usability (SUS1, SUS2, SUS3, SUS4, SUS5, SUS6, SUS7, SUS8, SUS9 and SUS10). For the positive items, the contribution to the overall usability score is calculated as the scale position minus one. For the negative items, the contribution is the scale position minus five. These scales include all values from 0 to 4 (with 4 being the most positive response). The total score is then multiplied by 2.5 to obtain the overall value of usability of the platform in the range of 0 to 100. The higher the SUS score, the greater the perceived usability of the system. A score below 50 represents a low level of usability, a score between 50 and 70 represents an acceptable system, a score between 70 and 80 represents a good level, a scores between 80 and 90 represents an excellent level, and finally, a score between 90 and 100 represents the best possible level. The usability score in the study is 62.52, which means that although system has acceptable usability it is below average (anything below 68 is below average (Capuano, Gaeta, Ritrovato, & Salerno, 2014; Kurosu, 2014)) and probably has serious usability problems.

4.4.3 Thematic analysis

At the end of the questionnaire, students were given an opportunity to add any suggestions or concerns they have about using the VLE. There were numerous comments, with responses from 27 of the 101 participants. Thematic analysis was then used as "a method for identifying, analysing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). The procedure of analysis for this study was guided by and adapted from Braun and Clarke's study (2006), which uses thematic analysis in qualitative research in psychology (see Table 3.1 in chapter three). All the responses from the participants were subjected to a manual thematic analysis using the coding template, with themes being defined as "patterned responses of meaning within the data set" (Braun & Clarke, 2006, p. 82).

Of the 27 responses, 23 were negative and 4 were positive. Several themes emerged from the qualitative sampling of participant comments from the open-ended question:

1. **Useful:** The VLE users found it useful for their study as it helps them to get motivated if they struggle with face-to-face lectures and/or not attending lectures. Typical comments included, for example, P9, *"I'm glad it's available"*, while P10 describes using the VLE, *"Overall, it's definitely a good learning space"*. P18 says, *"I've found it really useful to be able to access lecture notes"* and P24 describes using the VLE to catch up: *"I think it is extremely supportive towards studying and helps me get motivated if I struggle with the physical face-to-face lectures".*
2. **Poor mobile design:** The VLE does not work properly on a mobile phone. Users noticed that they had a problem with viewing certain pages and it was not easy for them to use it for accessing materials and learning related information. This is exemplified by this comment from P1, *"The VLE doesn't work on a mobile device, especially when viewing grades and timetable on iPhones"* and this comment from P8, *"I also find that accessing the VLE from a mobile device to be unnecessarily difficult. The site is buggy and simply doesn't work half the time I try to access it from my phone"*. P12 stated that it is not designed well from a mobile perspective, *"If a lecture is cancelled, we do not know unless we login to the VLE, which is not designed well from a mobile device perspective"*, while P27 commented: *"Very hard to use on mobile"*.
3. **Unintuitive design:** Some of the VLE users suggested that the VLE has an unintuitive interface and features, which means that it is not easily learnable and confusing for new users with different backgrounds and experience levels. For example, P8 stated, *"Having used the VLE for over two years, I have learnt how to make it work for the tasks I use it for. I do not think it is immediately obvious or clear how to use it"*. P15 stated, *"The VLE was difficult*

initially, but after a month or two the majority of what I need to use it for on a daily basis was clear. However, still, in my third year I don't think I utilise the VLE to its full potential due to a lack of knowledge". P11 said, *"It is confusing, especially for international and new students"*, P6 stated, *"The VLE is not intuitive"*, and finally, P27 said, *"Does not scale well with 21:9 monitor. 'Co-curriculum' navigation bar option is useless and the whole bar could benefit from changes. 'The Office' design and layout is terrible and unintuitive"*.

4. **Navigation:** VLE users found that regarding navigation, it is not easy for users to know what content is included/available in hidden or inappropriately named tabs/menu items. For example, P22 stated, *"The name of some tabs such as 'the office' is vague, doesn't say what is in that tab, and in the tab 'the office' it appears to contain a random variety of information"*, while P27 said, *"Far too many options hidden in drop down menus. Hard to navigate to certain options. Too many clicks required to access certain pages and login could be made easier. Design is inconsistent"*.
5. **Missing features:** The students highlighted some of the missing features that may help them use the VLE in a more productive way, stating that these features could save them time and they would not miss new material uploaded to the system. For example, P2 stated, *"[I] want to get email notification every time I get a notification on VLE"*. P12 said, *"System announcements should be integrated with emails/text messaging; if a lecture is cancelled, we do not know unless we login to the VLE"* and P4 said, *"I believe that [the] VLE needs to be more visually appealing to the naked eye"*. There were numerous comments about the search function. For example, P7 said, *"I know it has been suggested time and time again, but a basic search function would be really beneficial. Obviously, I am aware of the CTRL+F option, but this will only search the page you are on"* and P14 stated, *"I would like a search button on the VLE so that it is so much quicker and easier to find information"*.

6. **Training:** As the VLE can be adapted by lecturers at the universities, this means that the staff can use it based on their own needs. However, some of the participants stated that their lecturers are sometimes not sure how to reach a specific area or they add more information than is needed for that module. For instance, P7 stated, *"The issue I find is if you were to ask a lecturer where to find something, they themselves do not always know"* and P17 said, *"Teachers need to be better at using the VLE – it lacks consistency in terms of no overall standard of how the teachers use the VLE: some upload more than others; some use playback, some don't; some have more lecture materials such as notes, so if there was some standard, perhaps this would help consistency"*. Finally, P10 said, *"There were some modules with too many files and this made accessing information difficult"*.

In summary, students stated that there were too many files and in some cases files were duplicated in some modules, which made accessing the information difficult, while some lecturers did not provide much information on the VLE at all. This may be due to the way the module is designed however. Students stated that the VLE would be a far more useful tool if the staff were confident in using the features. Moreover, too many clicks were required to access certain pages and it was difficult to navigate to certain options. Furthermore, they suggested having a search engine and found accessing the VLE from a mobile device to be unnecessarily difficult. A few of them stated that although they have been using the platform for two or three years, they still find it difficult to use and it has overly complicated features. However, others think that the VLE was difficult initially, but after a month or two the majority of what they need to use it for on a daily basis was clear. Moreover, some stated that it is confusing, especially for international and new students.

4.5 Discussion

The primary objective of this study was to determine the usability of a VLE platform from the point of view of students in higher education and to identify common issues that students have when using it. In relation RQ1 the mean overall score for the usability items was 62.52 out of 100. Each of the system usability categories had below average usability scores, with the most important areas for concern relating to inconsistency and function integration. The majority of the free text responses refer to the usability challenges, and students seem to be saying that although these can be fixed easily, unfortunately, the service provider has not yet implemented appropriate functionality to fix these issues. Considering the importance of a VLE, and the fact that usability is known to affect technology acceptance levels (Ivanovic, Klasnja-Milicevic, Ganzha, Badica, Paprzycki, & Badica, 2018), and that usability of VLEs has an impact on learning, this is concerning.

In relation RQ2 there does seem to be interesting relationships in perceptions of users across the individual questions on the SUS and the themes identified. For example, SUS7 stated *'I would imagine that most people would learn to use the VLE very quickly'* with the majority of respondents (62.5%) agreeing or strongly agreeing, and SUS10 stated *'I needed to learn a lot of things before I could get going with the VLE'* with 53.5% disagreeing or strongly disagreeing. This would indicate that some students find it difficult to learn and some find it easy to learn. Beings as some of the themes identified, '*Unintuitive design*', '*Navigation*' and '*Training*' directly relate to this issue suggests that these responses are from the students that find it difficult to learn and are corroborating the reasons this is the case. This demonstrates that some students are well aware of the deficiencies of this particular VLE system and have made a number of specific recommendations. Based on this feedback, recommendations for improvements are as follows:

1. Staff need training about how a module should be designed on a VLE with relevant and important materials.
2. The number of clicks required to access certain pages needs to be as small as possible.
3. Consistent navigation is needed with appropriate naming conventions.
4. Unnecessary features need to be identified and removed/hidden.
5. Add search functionality and enable (email) notifications for updates on the VLE e.g. content uploaded.

Although the majority of these recommendations have been reported in previous research, with a number being standard usability guidelines (Nielsen, 1993; Nielson, 2000). It is worrying that these issues still persist and have not been taken on board by the developers of this VLE platform.

In relation to RQ3, it should be noted that although there seems to be some agreement between the SUS and free-text responses, the fact that the SUS found an "acceptable" level of usability is surprising, considering that some of the free-text responses indicate some serious usability issues. These would not have been identified by use of the SUS alone. This may be explained by the range of students surveyed and their differing levels of experience and subjects studied. More work therefore is needed to analyse these results based on these factors to determine the representativeness of some of the responses received and to see whether these factors have an impact on student's perceptions of certain usability issues. It is clear though that usability is an issue for a significant number of students and the changes needed are well known and relate to pre-existing usability guidelines and patterns e.g. (Nielson, 2000).

4.6 Summary and Conclusions

This study confirmed that although the VLE platform tested has acceptable levels of usability, they are below the average level as defined by the SUS due to some significant usability issues highlighted by the free-text responses. The thematic analysis supports these results and suggests areas for improvement. VLEs are complex and have numerous features for a variety of different stakeholders. Further work is therefore needed by service providers to identify common usability issues (and resolve them) and for module lecturers to be more aware of usability issues and appropriate E-learning design principles.

The findings of this chapter aim to address thesis objectives 2 and 3 (To evaluate the usability of a commonly used VLE in higher education using the state-of-the-art methods and To identify specific usability issues that users have with current VLEs and produce a set of usability guidelines).

There seems to be an issue here with students rating usability as "acceptable" even though there are clear issues which should question usability and therefore its level of acceptance. TAM is another pre-existing standard model used to measure acceptance level and is based on a number of usability attributes such as PU and PEOU etc. This is in agreement with Harrati et al. (2016) who suggested that usability needs to be investigated further and how it affects students PU and PEOU. The next Chapter then investigate the TAM as a model, and then also how the individual usability factors combine to produce "acceptance".

When comparing the SUS score and the free text comments, this does imply that the validity of using the standard usability questionnaire on its own needs further investigation, which is then explored further in Chapter 6.

Chapter 5: The Influence of Usability, Learnability and Perceived Enjoyment on Technology Acceptance.

The usability issues identified in Chapter four using SUS, however, here the SUS questions will be divided into usability and learnability. In the SMS we collected the methods and issues with usability of the E-learning. The TAM model is one of the most common models that has been used in the past few decades, therefore we will be addressed the adopt it by adding the usability, learnability (independently) and perceived enjoyment here in more detail using multiple linear regression to determine the relationship between usability, learnability and perceived enjoyment and the TAM. Specifically, we expand the TAM and make a contribution by evaluating learnability independently from usability and perceived enjoyment to provide a comprehensive picture of their influence. Another contribution in this chapter is addressing whether there are extensions to the TAM that could improve its use for the evaluation of the ease of adoption of E-learning systems. From the mapping study, three factors were identified that could be used to extend the TAM: learnability, usability, and perceived enjoyment.

5.1 Introduction

The TAM was developed from the theory of reasoned action (TRA) by Davis, Bagozzi and Warshaw (1989), to describe a person's I.T. acceptance behaviour. The aim of the TAM is to explore the reason behind the attitudes and views of the users on acceptance to use I.T. or not. It also aims to develop a description of the acceptance to use I.T. (Davis et al.,1989). The TAM has been used to predict the behavioural intention of several technologies, for instance, electronic-commerce, electronic-banking, E-learning, and many others (Deng, Doll, Hendrickson, & Scazzero, 2005). The original TAM (Davis et al.,1989) is shown in Figure 5.1 and contains 5 main features.

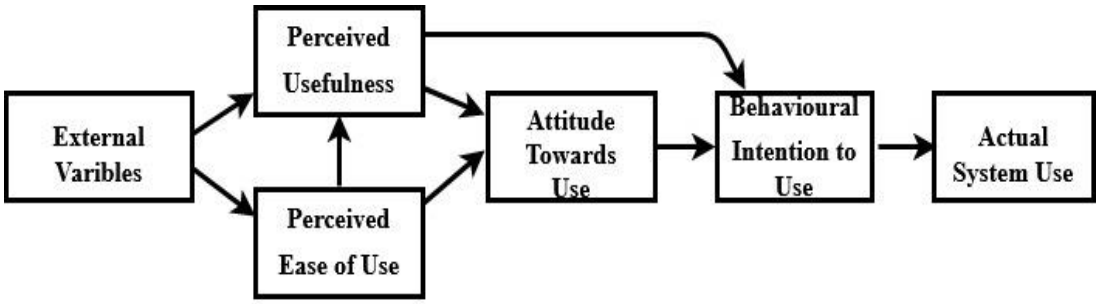

Figure 5.1: Technology Acceptance Model

Davis et al, (1989) define Perceived Ease of Use (PEOU) as how a person perceives that using the system would be effortless. Perceived Usefulness (PU) refers to "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis et al., 1989). Intention to use (IU) is defined as an indication of the willingness of a person to perform a particular behaviour (Ajzen, 1985). Attitude towards behaviour (ATB) refers to an individual feeling positively or negatively about accomplishment of the particular behaviour.

As well as the original TAM, several other models have been designed to gain an understanding of the factors that have influenced the acceptance and use of technologies. These include: TAM2, the theory of planned behaviour, the motivational model, the decomposed theory of planned behaviour, the Unified Theory of Acceptance and Use of Technology (UTAUT) model, and the TRA (Dulle & Minishi-Majanja, 2011). The original TAM is still often used though due to its comprehensiveness and high explanatory power compared to other theories of acceptance and use of technology.

When applied to E-learning platforms (the area of this study) the TAM shows that a user's behavioural intention to use a Virtual Learning Environment (VLE) is significantly affected by the PU and PEOU (Elkaseh, Wong, & Fung, 2015; Liu, Liao, & Pratt, 2009; Ong, Lai, & Wang, 2004; Zhang, Zhao, & Tan, 2008).

There have been criticisms though of the TAM, with analysis showing that results are not totally consistent or clear. It has been suggested that significant factors are not included in the model (Legris, Ingham, & Collerette, 2003) as it does not include essential measures related to users' perception of the usability of the technology (Holden & Rada, 2011). A number of studies have therefore suggested additional factors which may also be useful for integrating with the TAM (Elkaseh et al., 2015; Farahat, 2012; Liu et al., 2009; Masrom, 2007). Although ease of use is included in the original model, according to Quesenbery (2001), the usability of a product contains four key factors: how and why people use it, evaluation of the product, factors beyond 'ease of use', and a user-centred design (when their requirements, goals and asks are met). Although ease of use is a component of usability, it does not consider all features of a system's interface design e.g. speech recognition, colour coded buttons, and text icons (Overbeeke, Djajadiningrat, Hummels, & Wensveen, 2002). Usability means more than just 'ease of use' (Snijders, van Lin, & Hessels, 2004). Furthermore, according to Lin, (2013), exploring the relationship between TAM and usability in more details is needed. Therefore, in this Chapter other components related to usability have been considered such as learnability and perceived enjoyment as additional external variables for the TAM. The above studies demonstrated that there are a number of factors that can influence the acceptance and usability of E-learning platforms that are not currently included in the traditional TAM. For this study, we are therefore proposing the use of usability (in its more general form), and learnability and perceived enjoyment (as a proxy for satisfaction) as individual factors; all from Nielsen's (1993) framework.

The focus of this study then is to determine whether these additional features/external variables can improve the TAM by investigating the relationship between usability, learnability, PE, PU and PEOU as recommended by Harrati et al. (2016).

This study in this chapter is organised as follows: Section 5.2 describes background and related work, Section 5.3 provides the research hypotheses, Section 5.4 describes the methodology, and Section 5.5 presents the results of the evaluation analysis. The discussion is presented in Section 5.6, and the conclusions are presented in Section 7.

5.2 Research Hypotheses

Figure 5.2. shows our suggested potential additions to the TAM, adding Usability, PE and Learnability as well as the relationships between these additions and the original model. It should be noted that we are not aiming to test relationships that have been assessed in previous work, and are focussing on new parts of the proposed model. In order to test this new model, the following research hypotheses were formulated:

H1a: Usability has a statistically significant effect on students' Perceived Usefulness of the VLE in higher education.

H1b: Perceived Enjoyment has a statistically significant effect on students' Perceived Usefulness of the VLE in higher education.

H2a: Perceived Enjoyment has a statistically significant effect on students' Perceived Ease of Use of the VLE in higher education.

H2b: Learnability has a statistically significant effect on students' Perceived Ease of Use of the VLE in higher education.

H3a: Usability has a statistically significant effect on students' Perceived Enjoyment of use of the VLE in higher education.

H3b: Learnability has a statistically significant effect on students' Perceived Enjoyment of use of the VLE in higher education.

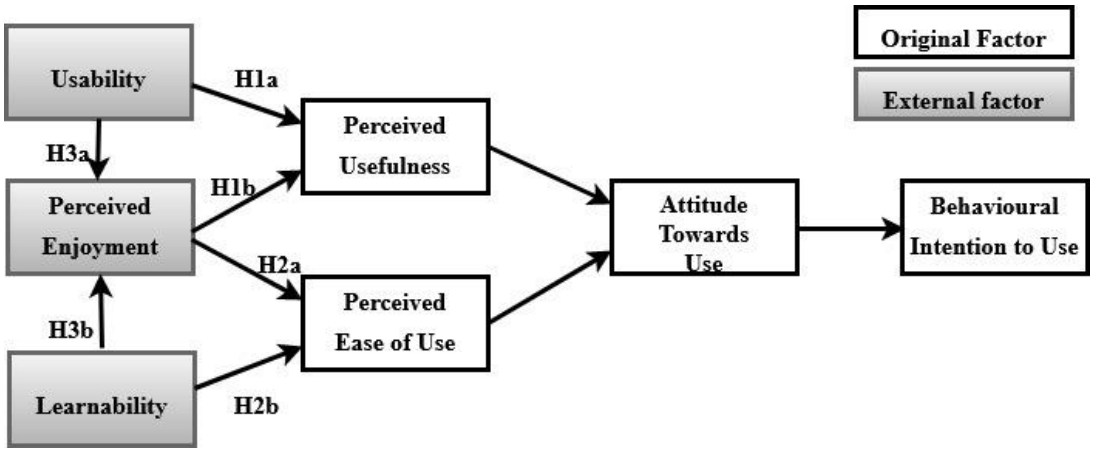

Figure 5.2: The research model

5.3 Research Methodology

In this chapter, an online questionnaire has been used to explore factors that may affect the TAM and the students continued use of a VLE in higher education (see Appendix C.4 System evaluation). 162 responses were received and have then been used in the study in this chapter to investigate the TAM. All participants agreed to participate and signed an informed consent form (see Appendix A.3 and Information sheets, in Appendix A.2 and describing the research objectives and the methodology were sent to all the students.

To measure usability and learnability (the new factors), we used the SUS, which contains ten items (Brooke, 1996). The SUS contains two reliable subscales and they are independent variables which measure usability with eight items (items 1, 2, 3, 5, 6, 7, 8 and 9) and learnability with two items (items 4 and 10) (Borsci, Federici, & Lauriola, 2009; Lewis & Sauro, 2009). In a number of studies, the SUS has been divided to measure learnability and usability independently (Katsanos, Tselios, & Xenos, 2012; Kortum & Sorber, 2015). Therefore, in this research we measured usability and learnability independently. PE was measured using four items, two based on Davis et al, (1992) and one each from Childers, Carr, Peck and Carson (2001) and Lee et al. (2005)

For the pre-existing factors in the TAM, PU was measured using six items based on Davis et al, (1989). PEOU was measured with five items from Davis et al, (1989), attitude was measured with five items taken from different publications (Compeau, Higgins, & Huff, 1999; Davis et al, 1989; Fishbein & Ajzen, 1975; Taylor & Todd, 1995; Thompson, Higgins, & Howell, 1991). IU was measured with three items, two from Roca, Chiu and Martínez (2006) and one from Lee, Cheung and Chen (2005) . In total there were 33 questions in the final questionnaire. This study used an online questionnaire to collect the data using Google Forms. Using an online survey made the questionnaire available to all the students and helped us to collect a complete set of data. An email with the questionnaire link and information sheet was sent to all the students once the ethical approval had been received from the university, and an advertisement was displayed on the VLE for all the students, which means that students could fill in the questionnaire at their convenience.

5.3.1 Profiles of respondents

The demographic information (see Appendix C.1 Profiles of respondents) of the 162 respondents has been tabulated using descriptive frequency analysis (Table 5.1). The category range of age (18–27, 28–37, 38–47 and over 48 years), gender, level of study (undergraduate or postgraduate), area of origin (United Kingdom (UK) and international) the description and characteristics of students as the main users of the VLE. The demographic section also contained questions related to the School.

Table 5.1: Profile of participants and their expertise

		Frequency	**Percentage**
Age (in years)	18–27	154	95.1
	28–37	7	4.3
	38–47	1	0.6
	48+	0	0.0

	Total	**162**	**100%**
Gender	Male	61	37.7
	Female	101	62.3
	Prefer not to say	0	0.0
	Total	**162**	**100%**
Level of Study	Undergraduate	139	85.8
	Postgraduate master's taught	23	14.2
	Total	**162**	**100%**
Area of Origin	UK	117	72.2
	International	45	27.8
	Total	**162**	**100%**
School Name (Major)	School of Health & Rehabilitation	3	1.9
	School of Medicine	3	1.9
	School of Nursing and Midwifery	4	2.5
	School of Pharmacy	17	10.5
	Keele Management School	17	10.5
	School of Humanities	17	10.5
	School of Law	15	9.3
	School of Politics, International Relations & Philosophy	12	7.4
	School of Social Science & Public Policy	17	10.5
	School of Computing & Mathematics	11	6.8
	Schools of Life Sciences	21	13.0
	School of Chemical & Physical Sciences	9	5.6
	School of Psychology	12	7.4
	School of Geographical Sciences, Geology and the Environment	4	2.5
	Total	**162**	**100%**

5.3.2 Experience and duration of study using the VLE

This section relates to the experience and time spent using the VLE (Table 5.2). Part one of the questionnaire was used to determine the last time the respondent used the VLE, with three alternatives of less than one week, less than one month and more than one month. The demographic section also contained questions related to the duration of study at Keele University (less than one year, one–two years, or more than three years) (see Appendix C.2

Profiles of respondents Experience and duration of study using the virtual learning environment). This shows that the majority of the students use the VLE regularly for their studies and we had respondents from different levels of experience of using the VLE.

Table 5.2: Experience and duration of study

		Frequency	Percentage
Last Time You Used the VLE	Less than one week	159	98.1
	Less than one month	2	1.2
	More than one month	1	0.6
	Total	162	100%
Duration of Study at Keele University	Less than one year	57	35.2
	One–two years	80	49.4
	Three or more years	25	15.4
	Total	162	100%

5.4 Results and Analysis

5.4.1 Pilot test

To test the reliability and consistency of the questionnaire, a pilot test was conducted with 30 participants and analysed using SPSS version 24. The participants were undergraduate and postgraduate master's students from Keele University and appropriate amendments to the questionnaire design were then made (final design described above). The level of Cronbach's alpha was more than 0.7, which confirmed the high level of the internal consistency of the measurements as suggested by Hair et al. (2010).

5.4.2 Reliability of measurements main test

For the full set of results, we then conducted a reliability test of measurement using Cronbach's alpha (for the reliability analysis results, see Table 5.3). The level of Cronbach's alpha was more than 0.7, confirming the reliability of the variables. For the purposes of analysis, the negative statements contained in the SUS (i.e. Q2, Q5 and Q7; learnability Q1 and Q2; and IU Q2) were recoded i.e. where the negative value is five, one is used as a new value, for four we

used two, three remains unchanged as it is the neutral point.

Table 5.3: Reliability measurements

No.	Variable	Cronbach's Alpha
1	Usability	.892
2	Learnability	.749
3	Perceived Usefulness	.922
4	Perceived Ease of Use	.872
5	Attitude	.792
6	Intention to Use	.830
7	Perceived Enjoyment	.901

5.4.3 Normality

As we are using parametric analysis methods (Pearson correlations and regression), it was necessary to test for normality. According to Hair, Anderson, Babin and Black (2010), this refers to the "degree to which the distribution of the sample data corresponds to a normal distribution". The data can be assessed for normality statistically by obtaining the scores' kurtosis and skewness. Kurtosis is the measure of the peak or flatness of a distribution (Hair et al., 2010), while skewness is the measure of the symmetry of the data distribution (Tabachnick & Fidell, 2007). When the values of kurtosis and skewness are equal to zero, the distribution is normal. The mean, standard deviation, skewness and kurtosis for the variables in both models are shown in Table 5.4. The results are within the acceptable range of -8 to +8 for kurtosis and -3 to +3 for skewness, as recommended by Kline (2011). Based on the results, all the variables were normally distributed.

Table 5.4: Mean, standard deviation, kurtosis and skewness for the scales used in the model

	N	Mean	Standard Deviation	Kurtosis	Skewness
Usability	162	3.66	0.78	0.245	-0.626
Learnability	162	3.76	1.08	0.000	-0.781
Usefulness	162	3.97	0.82	0.947	-0.860
Perceived Ease of use	162	3.77	0.77	0.416	-0.582

Attitude	162	3.92	0.70	3.923	-1.383
Intention to Use	162	4.18	0.83	2.879	-1.563
Perceived Enjoyment	162	2.98	0.87	0.551	-0.121

5.4.4 Exploratory factor analysis (EFA)

Factor analysis is used to investigate and deal with data sets where there are large numbers of the variables using SPSS 24 (Song, 2010). The results of EFA show that the Bartlett's test of sphericity was statistical significantly ($p>0.000$), which indicated an adequate correlation among the variables. The Kaiser-Meyer-Olkin (KMO) evaluation of the sample was adequate with 0.888, showing the suitability of the data for EFA. The KMO and Bartlett's test results are shown in Table 5.5. The results are higher than 0.5, which indicates that the sample size is adequate for factor analysis to be conducted.

Multicollinearity is important to ascertain whether there are correlations between the variables (Hair et al., 2019). To establish a hypothesised model (Figure 5.2), the causal effect relationship must fulfil the requirement of a degree of correlation less than the critical value of 0.9 (Hair et al., 2019; Tabachnick & Fidell, 2016). Table 5.6 presents the detailed association among the variables. All the correlations show significant values less than 0.9, which confirmed the absence of a multicollinearity issue in the research journey of model testing. The Holm-Bonferroni method was used with sequential correction to account for type I error in the multiple regression analyses conducted in the study (Holm, 1979). The PE v learnability correlation is .160* with significance level of 0.042 without an adjustment for multiple tests this would appear to be significant at the $p<0.05$ i.e. one star. It is not significant if we apply an adjustment. Table 5.6 shows the Holm adjusted significance figures. An online Excel calculator developed by Gaetano (2018) was used to calculate the adjusted p-values.

Table 5.5: The pattern matrix

KMO and Bartlett's Test		
KMO Measure of Sampling Adequacy		.888
Bartlett's test of sphericity	Approx. Chi-Square	3764.261
	df	528
	Sig.	.000

Table 5.6: Correlation among variables

	Usability	**Learnability**	**PU**	**PEOU**	**Attitude**	**Intention**	**PE**
Usability		.400**	.346**	.588**	.432**	.376**	.308**
		6.674E-08	3.286E-06	9.604E-17	4.620E-09	4.035E-07	3.402E-05
Learnability			.296**	.471**	.353**	.206**	.160*
			6.383E-05	1.300E-10	2.068E-06	4.310E-03	4.20E-02
PU				.562**	.575**	.477**	.364**
				3.761E-15	5.867E-16	6.638E-11	9.448E-07
PEOU					.658**	.387**	.481**
					9.744E-22	1.779E-07	4.800E-11
Attitude						.453**	.339**
						7.358E-10	5.056E-06
Intention							0.092
							1.218E-01
PE							
** Correlation is significant at the 0.01 level (2-tailed)							
* Correlation is significant at the 0.05 level (1-tailed)							

5.4.6 Hypotheses testing

Based on the Usability, PE and Learnability, three hypotheses were formulated as described in Section 5.2. The test of the significance based on the multiple regression statistics was conducted on all the research hypotheses. The regression data for each hypothesis is shown in Table 5.7. We include both usability and PE as independent variables in a single regression

with the dependent variable of PU. Each of the hypotheses is discussed in detail in the following section.

Table 5.7: Regression statistics for the hypotheses

Path	Independent variable	Dependent variable	Un-standardised coefficients		T	p	R^2	F	Result	Collinearity statistics	
			B	Std. error					Tolerance	VIF	Result
H1a	Usability	PU	.269	.078	3.448	.001	.193	19.015	.905	1.105	Supported
H1b	PE		.267	.070	3.804	.000					Supported
H2a	PE	PEOU	.366	.055	6.629	.000	.390	50.852	.974	1.026	Supported
H2b	Learnability		.287	.045	6.440	.000					Supported
H3a	Usability	PE	.322	.091	3.526	.001	.096	8.473	.840	1.191	Supported
H3b	Learnability		.036	.066	.537	.592					NOT Supported

Hypothesis 1

H1a: Usability has a statistically significant effect on students' Perceived Usefulness of a VLE in higher education.

We conducted regression analysis to test the first hypothesis (a & b), where usability and PE were the independent variables and PU was the dependent variable. A p-value of <0.001 was given from the regression analysis, which means that there is a significant relationship between usability and PU. The unstandardized B coefficient shows the degree to which usability predicts PU; a B = 0.269 PU unit increase is predicted with each usability unit increase, which indicated a positive relationship with the PU.

H1b: Perceived Enjoyment has a statistically significant effect on students' Perceived Usefulness of a VLE in higher education.

The results of the regression analysis for testing the second independent variable PE in the first hypothesis show a significant relationship ($p<0.001$) with PU as the dependent variable. The variable PE predicts PU, the unstandardized B coefficient of B = .267 indicates the extent a .267 unit increase in PU is predicted with every unit of increase in PE, meaning the PU also a positive relationship with the PE. The regression equation shows that .193 was the calculated value of R^2, which indicates that the predictor variables usability and PE explain 19.3 per cent of PU, the dependent variable, which is the variance explained by these two variables combined.

The F statistic tests the whole model and estimates that the dependent variable represents the average values of the dependent variable. The F test can be used to determine if the variations of two samples (or groups) differ (Bortz & Schuster, 2010). The range between zero and a large random number is the value of the F statistic. The F statistic for the regression model is 19.015, which means the regression model is significant. It also shows whether the model is statistically significant or not. Based on the result, it does that the new variables do offer more to the estimation capability of the TAM. This means we reject the null hypothesis and accept the alternative hypothesis.

Hypothesis 2

H2a: Perceived Enjoyment has a statistically significant effect on students' Perceived Ease of Use of a VLE in higher education.

Based on the obtained result of the regression ($p<0.001$ and $t = 6.629$), there is a significant relationship between the dependent variable PEOU and the independent variable PEOU. The regression of the unstandardized coefficient indicated that every increase in the PEOU for a unit, increase in the PE with .366, which shows a positive relationship between the PEOU and PE.

H2b: Learnability has a statistically significant effect on students' Perceived Ease of Use of a VLE in higher education.

Learnability was taken as an independent variable, while PEOU was a dependent variable to test the hypothesis with regression analysis. The results reveal a significant relationship between the variables ($p<0.001$ and $t = 6.440$).

The variable learnability explained 39.0 per cent of the variable PEOU. The ability of the variable learnability to predict the variable PEOU was indicated by the unstandardized coefficient .287, which also indicated that learnability has a positive relationship with the PEOU.

In the regression equation, the value of R^2 .390 shows that the variables PE and learnability explain 39.0 per cent of the variable PEOU. The value of the F statistic was (50.852), which means that the regression model was significant. Based on the result, it seems that the new variables do offer more to the estimation capability of the TAM. This means we reject the null hypothesis and accept the alternative hypothesis.

Hypothesis 3

To test this hypothesis, regression analysis was conducted.

H3a: Usability has a statistically significant effect on students' PE of a VLE in higher education.

Usability was a predictor variable and PE was a dependent variable. Based on the results, a significant relationship between the variables ($t = 3.526$ and $p<0.001$) can be observed. However, the unstandardized B coefficient was 0.36, which indicates the predictability of the variable PE, meaning that Usability had a positive effect on PE .

H3b: Learnability has a statistically significant effect on students' PE of a VLE in higher education.

Learnability was not statistically significant, as indicated in Table 5.7, on the PE of the E-learning (p = .592 and t = .537), as its p-value is definitely larger than the acceptable 0.05. However, the unstandardized B coefficient was 0.36, which indicates the predictability of the variable PE, which means that Learnability did not have a positive effect on PE.

Overall, the variables usability and learnability explained R^2= 09.6 per cent of the variable PE. The regression shows that there was a significant (F = 8.473). Based on the result, it seems that learnability does not offer anything to the estimation capability of PE on the developed model, while usability may improve the basic TAM. This means we failed to reject the null hypothesis and cannot accept the alternative hypothesis.

5.4.7 Summary of results

The direction of the regression coefficients indicates that PE and usability were jointly related to PU although the association was relatively weak (accounting for only 19 per cent of the variation in PU). PE and learnability were jointly associated with PEOU, with the association accounting for 39 per cent of the variation in PEOU. PE was related to PEOU; however, learnability was not. Usability and learnability were jointly associated with PE, with the association accounting for 9 per cent of the variation in PE. Usability was related to PE; however, learnability was not (see Figure 5.3).

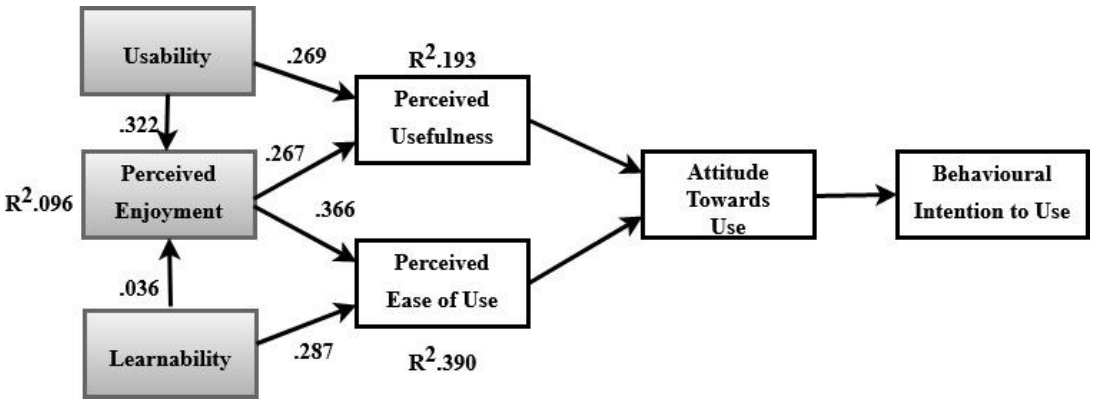

Figure 5.3: The model results of students

5.5 Discussion

This study aimed to investigate the relationship between various factors of usability that may be used to enhance the traditional TAM by examining a set of research hypotheses. The main results are that:

(1) Usability and Perceived Enjoyment have a statistically significant effect on students' Perceived Usefulness of a VLE.

(2) Perceived Enjoyment and Learnability have a statistically significant effect on students' Perceived Ease of Use of a VLE.

(3) Usability and Learnability do not have a statistically significant effect on students' Perceived Enjoyment of Use of a VLE.

These results can be explained by the fact that if students find a VLE usable and enjoy using it, their view of how useful it is to their learning is then affected. Also, if a platform is easy to learn, users will be able to use the platform more constructively, leading to actively enjoying the experience. Interestingly though, if a student enjoys/doesn't enjoy using the system and finds it easy/difficult to learn, this does seem to have an impact on how they perceive its ease of use. Therefore, if a VLE platform is usable and enjoyable, this means that students perceive it as useful, which in turn means that they accept to use it.

With regards to implications for the TAM, the coefficients for PE and Usability were statistically significant, which means that including these additional factors does offer more than PEOU alone to the estimation capability of the TAM. When estimating PEOU using learnability and PE, the coefficient for PE and learnability are significantly greater than 0, as indicated in Table 5.7. Therefore, it can be suggested that including usability, learnability and perceived enjoyment could be useful additional external variables for the TAM model.

It seems that the standard TAM model can be improve by adding the usability, learnability independently and perceived enjoyment. However, it seems that learnability has no effect on perceived enjoyment. These results support the results presented by Ramayah, Suki and Ibrahim (2005); Masrom (2007); and Park (2009).

This study has a number of limitations. First, the demographic of the respondents is not fully representative of the student body in the University. There were significantly more female participants than male, and most of the students were aged between 18 to 27 with little representation from mature students. Furthermore, there was not equal participation from all University departments, with some schools only being represented by a single student. Finally, this study was undertaken at a UK based institution and cannot be extrapolated to other countries as the results may be significantly different when using students from different societies and education systems.

5.6 Summary and Conclusions

In this chapter, extensions to the TAM that could improve its evaluation of the ease of adoption of E-learning systems have been investigated. The chapter also aimed to explore the relationship between the usability, learnability and PE and usefulness of a VLE, address the relation between learnability, PE and PEOU of the VLE, build a new model based on the TAM, and address a set of research hypotheses. It was concluded that usability, learnability and PE can improve the TAM and it may be valid to add them to the original model as they take into account more factors than just ease of use. The results of this study have implications not only for any users of the original TAM, but also for VLE developers looking to increase the acceptance of their platforms and the consequent support for learners. The findings of this chapter aim to address thesis objective 4 (To investigate whether there are extensions to current

usability models and methods that could improve their use for evaluating the usability of VLEs) and emphasise the findings of the previous chapter to achieve objectives 3 and 4 (see Section 1.2). In the next chapter, an in-depth investigation is carried out using objective and subjective measures to assess the usability of the VLEs in higher education based on actual use.

Chapter 6: Usability evaluation of Virtual Learning Environments using subjective and objective measures

In Chapter Four there was a difference between students' responses to the SUS questionnaire and what they wrote in free text responses. In Chapter Two, it was found that there is currently less focus and use of evaluation techniques based on actual use. Therefore, this chapter describes a novel combined (subjective and objective) method that has been employed to assess the usability of the virtual learning environment (VLE) used at Keele University (Blackboard) by utilising a combination of objective (via measuring the user's achieved interactions with the system) and subjective (system usability questionnaires) measures and then comparing the results.

6.1 Introduction

Learning technologies and online platforms have become an important part of Higher Education, with students and teachers expecting high quality learning and teaching via tools such as VLEs. However, a learning platform is much more attractive to the user if it is usable and interesting at the same time (Hassenzahl et al., 2000). Therefore, the users' perspective needs to be considered in any evaluation of Electronic learning (E-learning) platforms. Although several studies have been conducted in this area, a systematic mapping study by Nakamura et al. (2017) identified a need for more research, as none of the identified evaluation techniques provided feedback with specific suggestions to correct the identified problems. Therefore, further investigation is required in different educational institutions and levels of education, and with more learning platforms (Orfanou et al., 2015), using different usability evaluation techniques.

Usability though is difficult to measure and is often evaluated by subjective assessment questionnaires (Abuhlfaia & de Quincey, 2018; Mtebe and Kissaka, 2015) such as the Questionnaire for User Interface Satisfaction (QUIS) and SUS. There are studies that have attempted to develop some standard heuristics that take into account both educational interaction and effectiveness related to interfaces (Mtebe & Kissaka, 2015; Ssemugabi & de Villiers, 2007; Zaharias, 2009) but these are still primarily subjective.

The goal of this study therefore is to investigate different methods of measuring usability factors and assessing usability, using both subjective and objective methods on a popular VLE platform (Blackboard), in order to get a fuller picture of how usable a system is (as using the SUS alone may not be sufficient, as shown by Harrati et al. (2016) and the study described in Chapter 4).

This Chapter is structured as follows. Section 6.2 describes the Usability Assessment. Summary of the background presented in Section 6.3. Section 6.4 presents our proposed Model of Usability Factors and Measures. The study methodology is described in Section 6.5, with data analysis in Section 6.6. Section 6.7 includes a discussion regarding the evaluation of the VLE platform and conclusions are drawn in Section 6.8. The following section describes the proposed usability evaluation model used in the study in this chapter.

6.2 Usability Assessment

Usability can be assessed in terms of objective or subjective measures. Objective measures are based on measurement of specific usability factors, such as Efficiency and Errors. Subjective measures of Usability are usually based on questionnaires where individual questions (items) are phrased as statements that a participant is asked to assess in terms of an agreement scale. The individual items may be related to Usability as a whole and/or individual usability factors.

For example, a statement related to Usability as a whole would be “I find the system easy to use”, while a statement related to a component such as Learnability would be “It would be easy for me to become skillful in the use of the system”. All such individual questions would require an answer based on a standardized agreement scale such as: Strongly disagree, Disagree, Agree, Strongly agree. The number of agreement options would be determined by the researcher and would be the same for all the individual questions. After validity and reliability assessment, a set of related items are assumed to be a Likert scale measuring Usability. For example, Davis and Ventakash (1996) explain the derivation validation of the “Perceived Ease of Use (PEOU)” scale that is part of the Technology Acceptance Model (TAM). Another scale is the SUS (Brooke, 1996), developed at Digital Equipment Corporation in the UK in 1986 as a tool to be used in usability engineering of electronic office systems. The scale is a 10 item scale which seeks the subjective opinion from a user regarding a particular device (Brooke, 1996),

Subjective questionnaires have the advantage that they offer direct assessment of the factor(s) of interest (Morgeson and Humphrey, 2006). Furthermore, they can be circulated to many system users with, hopefully, substantial response rates. However, they are based on opinions rather than actual performance measures. Furthermore, although difference among respondents can be related to demographic information, it can be difficult to ensure sufficient numbers of respondents with specific important characteristics (e.g., specific skill levels).

Objective measures are measures of performance obtained by monitoring users while they perform representative tasks, so are usually organized as formal experiments (Bommer, Johnson, Rich, Podsakoff, & MacKenzie, 1995). The measures are assumed to reflect specific usability factors, but are not usually direct measures of the factors e.g. measuring number of clicks for Efficiency. However, it is usually possible to target specific populations of users,

such as novices for usability experiments. We discuss measurement of the individual factors in the following subsections.

6.2.1 Learnability

Learnability is an important aspect of an E-learning platform. It concerns not only how easy it is for a novice to begin to use the system constructively, but also whether the system allows users to become more skilful as they become more familiar with it.

System learnability is likely to affect a student's engagement with their course and hence their academic performance, because the majority of United Kingdom (UK) universities require lecturers to use E-learning systems to deliver the materials and assessments. Furthermore, students that are able and willing to use such system can complete their educational assignments quickly and easily (Tamir, Komogortsev, & Mueller, 2008; Torun & Tekedere, 2015). Features such as good navigation and clear instructions support learnability (Dubey, Gulati, & Rana, 2012; Patrício, Fisk, Falcão e Cunha, & Constantine, 2011).

There are a variety of ways to measure learnability objectively, for example, the time that users need to reach a specified level of proficiency (Downey, Wentling, Wentling, Wadsworth, 2007). In addition, task scenarios have been considered in a number of studies. For example, Tamir et al. (2008) used a large set of tasks and digital video recordings to measure learnability, based on the time that first-time users take to perform specific tasks. However, a measure such as time taken to perform tasks can also be regarded as a measure of efficiency.

Subjective measures of learnability would relate to SUS questionnaire items such as "*It would be easy for me to become skillful at using the system"* in combination with items such as those related to Effectiveness and Errors discussed in Section 6.2.2 and 6.2.3.

To address the difference between novice performance with a system and the performance of individuals who have some experience of using the system, we suggest that "Improvement"

should be considered as a sub-factor of Learnability and objective and subjective measures would need to be obtained both from novice users and from more experienced users (see model proposed in Section 6.4).

6.2.2 Efficiency and Effectiveness

Efficiency relates to the completeness and accuracy of task performance when users want to achieve specific goals using an E-learning platform. The effort (i.e., the elapsed time) needed by a user to carry out a task has been often used as measure of efficiency (Berns, 2004; Grinberg & Hristova, 2011). Almansoori and Akre (2016) identified effectiveness (i.e. being able to complete a specific task correctly) and efficiency (i.e. being able to complete a task with as little effort as possible) as the most important factors that affect the performance of blended E-learning systems in higher education. Mutlu, Erorta and Yılmaz (2004) investigated whether students who use an E-learning system were more successful than those who did not use the system and concluded that the frequency of use of an E-learning application had a direct effect on success.

In the context of usability, our attempts to measure Efficiency suggest that it is worthwhile considering Effectiveness and Efficiency separately. Objective measures of effectiveness relate to the proportion of a set of tasks that a user can complete. Subjective assessments of effectiveness would equate to a questionnaire item such as *"I find it easy to get the system to do what I want to do".*

Objective measures of Efficiency relate to the time (or mouse clicks) it takes a user to successfully complete various tasks. It is important to note that the time taken working on tasks that are ***not*** completed cannot be easily interpreted. Some users may start to do a task and then give up quickly because they realize quickly that they cannot complete it, other users may spend a lot of time trying to complete a task until they finally decide that the cannot do it. Thus,

time spent on uncompleted tasks should not be included in a study of Efficiency. In order to determine whether or not the time taken to perform a task is appropriate it is important to have a baseline to assess participant performance. We have used the time taken by a skilled user to complete each of the required tasks as a baseline measure in this study. Subjective measures of efficiency would equate to questionnaire items such as *"Interacting with the system does not require a lot of mental effort".*

6.2.3 Errors

Unlike other factors defined by Nielsen (1993), Errors is not a positive characteristic. Errors, in terms of usability, relates to failure to complete tasks or unnecessary interactions with the system while performing a task. The first type of error can be measured as the number (or percentage) of a set of different tasks a user was unable to complete (Torun & Tekedere, 2015). Success rate can be measured as the number (or percentage) of tasks successfully completed, and can also be viewed as a measure of both Effectiveness and resilience to Errors. The second type of error can be measured by counting the number of mouse clicks and/or keyboard actions a user needs to complete a task compared with the minimum number of clicks needed to complete the task (Downey et al., 2007). This can also be considered as a measure of Efficiency. As in the case of measuring Efficiency, it is necessary to have some means of assessing whether the number of clicks is excessive or not. In this research, we have used the number of clicks a skilled user would take to perform each of the required tasks as a baseline. Subjective measures of Errors can be assessed with negative questions such as *"I found the system very complex/cumbersome to use"* in contrast Error Resilience could be assessed using positive questions such as *"I found the various functions in the system well integrated"*.

6.3 Summary of the background

In conclusion, the above studies aimed to investigate different (often singular) factors that affect the usability of various E-learning systems, using mostly quantitative methods. This study however aims to assess usability based on the student perspective, using a combination of both quantitative and qualitative methods to give a more comprehensive view of usability and more specific subsequent recommendations. Finally, individual factors of usability can be measured by both subjective and objective measures but further work is needed to identify relationships between these factors and measurement types, particularly in the area of VLEs.

6.4 A Model of Usability Factors and Measures

Figure 6.1shows the proposed model of usability factors and measures that underpin the study described in this chapter. It specifies Usability factors as linked boxes with headings identifying the factor, an example of a statement that might be used to assess that factor underneath and the Usability scale/instrument (the subjective measure) that they originate from. Compared with Neilson's model of Usability we have included Effectiveness as a separate concept from Efficiency because we measure the factors in different ways. We have modelled Errors as a sub-factor of Learnability, Effectiveness and Efficiency because lack of resilience to errors would affect all of these factors. We have also modelled "Improvement" as a sub-factor of Learnability, because we view Learnability as a factor related to gaining skill over time. The statements illustrating the factors are linked to the Usability scale they originate from. However, for our purposes we used a simplified questionnaire with only three items relating to Usability, Effectiveness and Resilience to Errors (see Figure 6.1).

The Usability factors are linked to objective measures with dashed arrows, and dashed boxes. Consideration of the ways in which factors can be measures also confirms that Errors should be regarded as a sub-factor of Efficiency and Effectiveness.

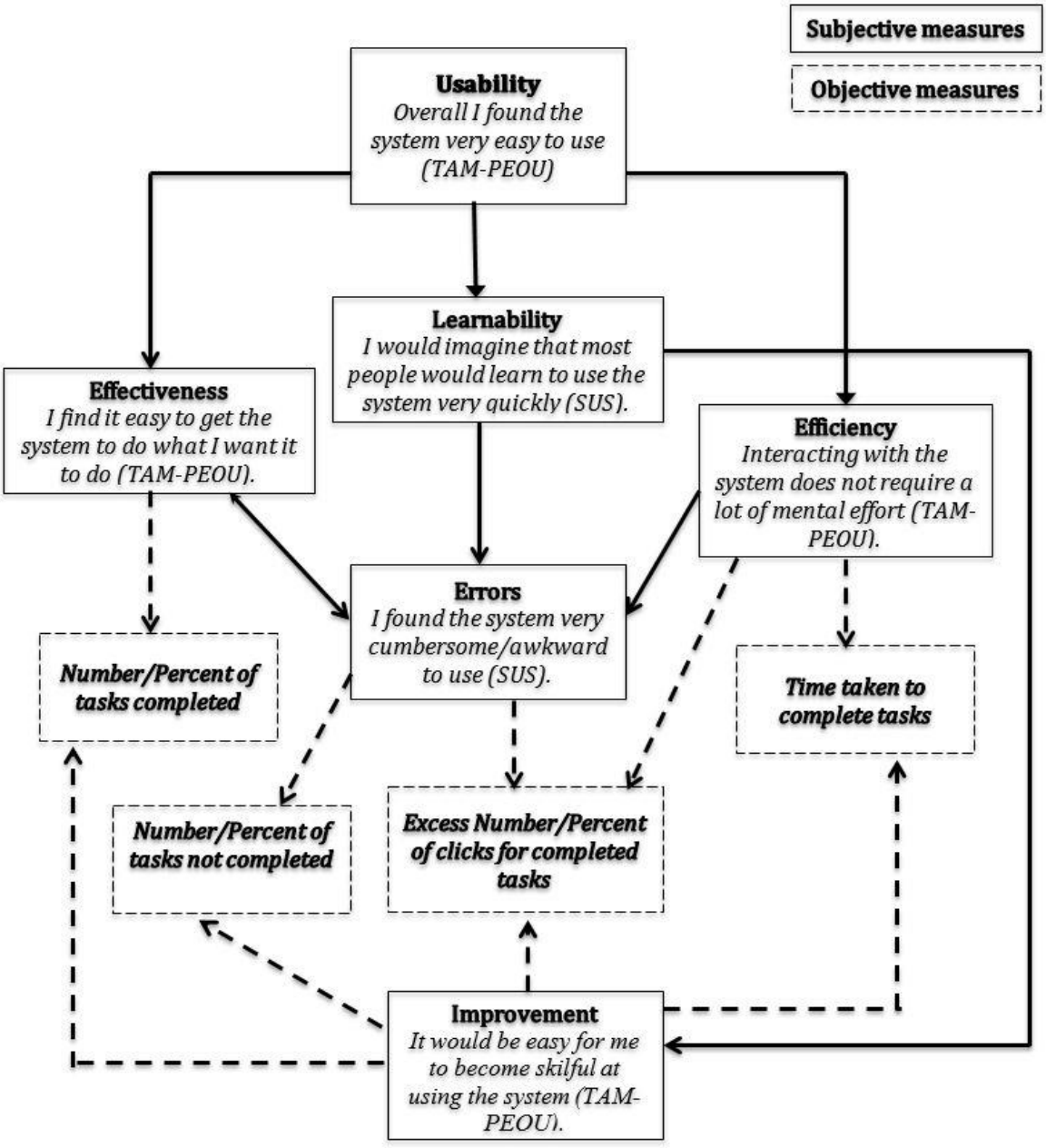

Figure 6.1: Model of Usability Factors and Measures

6.5 Methodology

6.5.1 Objective Measures

This study used observation as the main method for collecting the objective data. We recorded participants' interactions with the Keele University VLE with a screencasting tool (Snagit), whilst they performed the same tasks (described in 6.5.2) in two separate usability sessions. We selected observation as a method as it is a common method used in usability testing, and it allowed us to see how people use the VLE in a particular situation with almost no interaction from the observer (Nielsen, 1993; Rugg & Petre, 2007). The two separate sessions were used to investigate the impact of past experience i.e. **improvement**, by measuring the performance of the students when they were complete novices, and again after eight weeks after they had some experience of using the system during their day-to-day interactions with the VLE. From these recordings we were then able to calculate for each student in each session whether each task was completed correctly, the time spent on the task and the number of mouse clicks used while working on the task.

All of the measures described in the model above were collected for novice participants, and for a subset of the same participants after a period of 8 weeks during which they used the system to support their university course work. In order to determine a baseline for comparison, we performed each task and recorded the time taken and the number of clicks required.

6.5.2 Tasks

The following tasks given to participants were based on tasks used in a number of previous studies (Law, Blazic, & Pipan, 2007; Karahoca & Karahoca, 2009; Liu & Zhu, 2012; Qureshi & Irfan, 2009; Torun & Tekedere, 2015) and the researchers' experience of using the Keele Learning Environment (KLE). These tasks are typical of the tasks that a student user would perform as part of their normal course learning activities.

Task 1: Login to the VLE.

Task 2: Go to the personalise page, then choose any colour palette for all the elements on this page you like and save the settings.

Task 3: Select the module called Usability of the VLE from the course list.

Task 4: Locate the introduction to the module Usability of the VLE.

Task 5: Check the opening times of the campus library from the VLE.

Task 6: Download the lecture 2 slides in the module Usability of the VLE.

Task 7: Find the information on the timetable for this week.

Task8: Go to the updates page and check the title of the latest thing added to the list.

Task 9: Download the practical work 1, and then electronically submit it through the VLE (you do not need to write anything, just submit the file as downloaded).

Task 10: Go to the main page and select another module from the modules list, and open that module to view the course details.

Task 11: Return to the home page.

Task 12: Log out of the VLE platform.

The predefined Tasks were tested by three PhD students at Keele university to ensure that the tasks can be performed and completed and we can collect valid data to analyse.

6.5.3 Subjective Measures

For the subjective measures, a short questionnaire based on three standard usability questions (Lewis, 1994) was used at the end of each session.

The questions were:

Q1. Overall, I am satisfied with the ease of completing this task in this scenario.

Q2. Overall, I am satisfied with the amount of time it took to complete this task in this scenario.

Q3. I am satisfied with the support information (online help, messages, documentation) when completing this task.

Note in this case, the phrase "*complete this task in this scenario*" means completing the set of tasks that constitute a standard usage scenario. Thus, Q1 relates to **overall usability** given the set of tasks, Q2 relates to the effort it took for a participant to perform the set of tasks and measures **efficiency**, and Q3 relates to the support the system provides to help users complete their tasks and assesses **resilience** to **errors**.

The three questions were measured using a 7-point Likert scale with left and right anchors of 'Strongly Disagree' and 'Strongly Agree' respectively. Numerically, these were assigned a descending point value (i.e. "Strongly Disagree" is scored as 1, "Disagree" scored as 2, "Somewhat Disagree" as 3, "Neither Agree nor Disagree" is scored as 4, "Somewhat Agree" scored as 5, "Agree" as 6, and finally "Strongly Agree" as 7) such that a higher score indicates higher agreement.

The questionnaire was piloted with three postgraduate students from the School of Computing and Mathematics at Keele University, and then appropriate amendments were made.

6.5.4 Participants

An email was sent to all new first year students in the Computer Science department with a link to register to take part in the study (see Appendix A.5). As incentives, all participants received £20 for their time. For this study, there were 25 participants in the first session at the start of their first semester and 17 participants returned to complete the second session at the end of the first semester after using the system for 8 weeks.

All the participants were aged between 18 and 27 years. In the first session there were 16 male students and 9 female students, of which 18 were UK students and 7 international students. In

the second session, 17 students were unable to attend leaving 11 males and 6 female participants, of which 12 were UK students and 5 were international students.

All participants agreed to participate and signed an informed consent form (see Appendix A.7) Information sheets, which are available in Appendix A.6, describing the research objectives and the methodology were sent to all the students.

6.5.5 Experimental Environment and Procedures

To establish a test environment to monitor the performance of the students, a new module was developed on the VLE containing materials from a first-year programming module. Student participants who took part in the study were then set the tasks specified in Section 6.5.2 to complete on the VLE in the module during the two sessions (same tasks in both sessions). Figure 6.2 shows the overall procedure in the two sessions. The first observation session occurred in September 2018 and the second session was completed after eight weeks.

At the start of the session, we gave the students two minutes to read the tasks; no training was provided in the first session. If anything was not clear, they could ask for clarification before they started working on the tasks. They were told that if they were unable to complete a task, they could skip it. All the participants were allowed to continue for as long as they wanted. In the first session at the end of the session, we explained how to complete any tasks that the participants did not complete. Screen capture was set up on each machine to record what the participants were doing from the start. Recordings were then used to calculate the time taken for each task, the number of clicks to complete the tasks and whether the task was completed successfully or not. At the end of each session, the participants were asked to complete the questionnaire described in section 6.5.3.

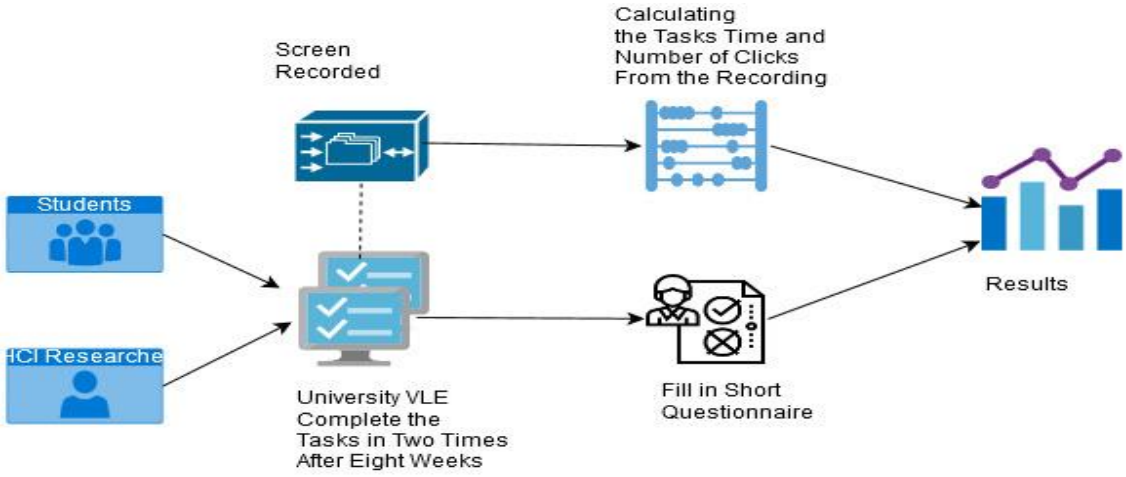

Figure 6.2: Proposed framework for usability evaluation

6.6 Data Analysis and Results

In this section we discuss our analysis process, present the task baseline data and then our analysis of the collected data.

6.6.1 Analysis Method

Although the basic design of our experiment was quite simple (i.e., obtain data from student participants performing the same set of tasks in two different sessions), analysis of the results was complicated by a number of issues:

- The tasks were designed to be of different difficulty, so the number of tasks completed or not completed cannot be analysed using the binomial distribution, because the binomial distribution assumes that the probability of success (or failure) is constant for each task.
- We obtained repeated measures for each participant, since participants attempted each task in each session. Statistically this means that we have correlated measures and any statistical analysis must take account of such correlations and standard t-tests or analysis of variance are invalid.

- Some students could not take part in the second session. The effect of this is that it would not be possible to investigate individual improvement (which is the usual method of adjusting for repeated measures) without discarding some of the data.
- We mentioned, in Section 6.2.2, the need to assess task efficiency only on completed tasks, but this introduces analysis problems. In particular, because of the inherent difficulty of tasks varies and the fact that different participants completed different tasks, the total effort for completed tasks was not comparable between different participants. In addition, even for the same participant, total effort for completed tasks would not be comparable between sessions if he/she completed different tasks in each session.
- An issue when evaluating improvement is that the measures of efficiency should eventually converge on the minimum values for clicks and effort required for a task. This means that the variance among participants will decrease over time. The impact of this is that the estimates of the variance among participants will be heterogeneous while the standard assumptions for t-tests and analysis of variance are that variances are stable.

There are techniques that could be used to increase the comparability of the measures per participant, such as giving an effort penalty for uncompleted tasks (based, for example, on the maximum time taken to complete the task plus an extra penalty) and using weighted average for the success rate (with weights based on the difficulty of the task as shown by the baseline effort for each task). However, such techniques complicate both data preparation and data analysis, and make it difficult to trace the data analysis to the raw data. For this reason, we began by analysing our data using some simple descriptive statistics that we hoped would

deliver clear enough results without attempting to use more sophisticated statistical analysis techniques.

The method we used to analyse the efficiency data was to estimate the time an average participant would take to complete each task and the number of mouse clicks that were required and compare that with the baseline estimate of effort and clicks for the tasks. For each of the 12 tasks, we took the average time and clicks from the participants who successfully completed the task ignoring the results of participants who did not complete the tasks. This we did separately for each session. The average time and clicks for each task in each session could be compared with the baseline values for each task. In addition, the sum of the average time and clicks provides measures of average efficiency across the set of tasks and can be compared with the total time and clicks of the baseline.

6.6.2 The Task Baselines

The baseline number of clicks and effort are shown in Table 6.1. The baseline confirms that the overhead of completing the tasks varies considerably from Tasks that can be completed in 2 seconds to Task 6 and Task 9 that take 13 and 16 seconds respectively for a skilled user of the VLE to complete.

Table 6.1: The Task Baselines

Tasks	**Task Action**	**Baseline Clicks**	**Baseline Effort** (seconds)
Task 1	Login	6	9
Task 2	Personalise colour	3	6
Task 3	Find module	2	4
Task 4	Get module intro	2	5
Task 5	Find Library hours	3	4
Task 6	Download lecture slides	6	13
Task 7	Find timetable	2	3
Task 8	Check updates	2	3
Task 9	Get practical work	8	16

Task 10	Find another module	2	2
Task 11	Go to Home page	1	2
Task 12	Logout	1	2
Total		**38**	**69**

6.6.3 Effectiveness and Improvement

Figure 6.3 shows the success rates of the 12 tasks for 25 participants in the first session and 17 participants in the second session. The success rate for the first session was 82.33%. In that session, tasks 5 and 6, which were to check the opening times of the campus library from the VLE, and download the lecture 2 slides had the lowest success rate. The success rate of the usability test in the second session was 88.24%. Tasks 5 and 6 again exhibited the lowest success rates while tasks 7 and 8 had a substantially increased success rate compared with session 1. Overall the success rate was quite good but showed highlighted problems with specific tasks.

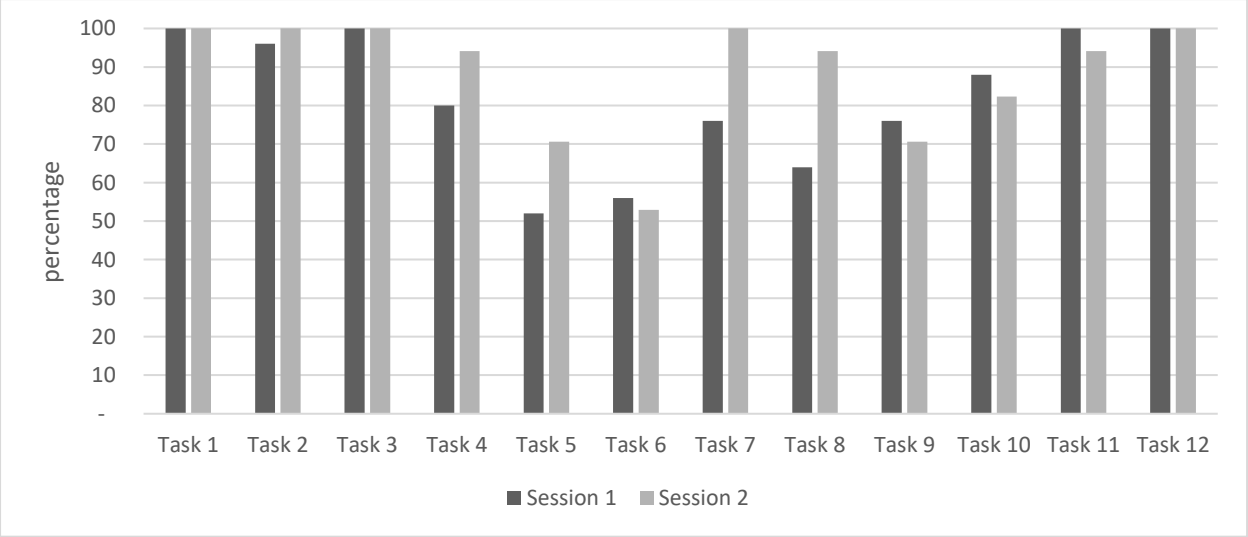

Figure 6.3: Number of participants who successfully completed the tasks in two sessions

6.6.4 Efficiency and Improvement

In this section we report the results of analysing the time taken, and the number of clicks required for completed tasks and compare the averages with the relevant baseline.

6.6.4.1 The Average Time per Task

Table 6.2 shows the mean and standard deviation (SD) of the time taken for each completed task in each session. The sum of the session 1 mean task time is 245.64 seconds. This can be interpreted as the time an average student with no experience of the VLE would take to complete the 12 tasks. This is 3.6 times longer than the baseline of 69 seconds. The sum of the session 2 task mean is 201.34. Therefore, there appears to have been some improvement. The average time taken to complete the tasks generally decreased in session 2. The two exceptions to this are tasks 3 and 9, where the time taken increased. The result for task 9, which involved downloading and submitting a document may be unreliable as several students misunderstood the task, and there are other factors that can affect this (such as download speeds) which can artificially increase the time taken. However, compared with the sum of the baseline task times of 69, the improvement is small since an average participant would have still have taken 2.9 times longer than a skilled user.

Table 6.2: The average and SD of time taken in two sessions

	Session 1			**Session 2**			**Baseline**
	N	Mean	SD	N	Mean	SD	
Task 1	25	18.52	2.87	17	15.88	3.24	9
Task 2	24	28.08	14.33	17	16.94	11.44	6
Task 3	25	10.76	7.75	17	11.71	6.81	4
Task 4	20	14.75	8.51	16	14.56	11.33	5
Task 5	13	39.85	18.52	12	31.50	25.25	4
Task 6	14	31.00	15.00	9	21.00	6.54	13
Task 7	19	11.21	6.91	17	3.82	3.97	3
Task 8	16	11.56	22.02	16	5.25	1.95	3
Task 9	19	63.42	19.77	12	70.25	22.24	16
Task 10	22	12.36	7.48	14	6.43	1.70	2
Task 11	25	2.04	0.20	16	2.00	0.00	2
Task 12	25	2.08	0.28	17	2.00	0.00	2
Total	**247**	**245.63**	**123.64**	**180**	**201.34**	**94.47**	**69**

6.6.4.2 The Number of Clicks per Task

Table 6.3 shows the mean and standard deviation (SD) of the number of clicks taken for each completed task in each session. Like the time per task, the number of clicks taken generally decreased in session 2 compared with session 1. The exceptions are tasks 3 and 9, The sum of the average number of clicks session 1 average is 70.96. The sum of the average number of clicks per tasks in session 2 is 62.73. Therefore, there appears to have been some improvement. However, compared with the sum of the baseline number of clicks of 38, the improvement was small. In session 1 an average participant would have taken 1.9 number of clicks more to have completed the tasks than a skilled user and in session 2 an average participant would have taken 1.7 number of clicks more than a skilled user.

Table 6.3: The average and SD of clicks taken in two sessions

	Session 1			**Session 2**			**Baseline**
	N	Mean	SD	N	Mean	SD	
Task1	25	8.52	0.51	17	7.29	0.92	6
Task2	24	3.79	1.02	17	3.88	1.32	3
Task3	25	3.32	1.57	17	2.47	0.62	2
Task4	20	3.85	1.04	16	4.06	2.64	2
Task5	13	9.69	4.29	12	10.92	5.76	3
Task6	14	10.50	3.16	9	8.00	4.44	6
Task7	19	3.58	1.26	17	2.29	0.59	2
Task8	16	4.31	4.11	16	3.50	4.72	2
Task9	19	16.16	5.47	12	15.83	5.11	8
Task10	22	3.64	1.47	14	2.43	0.51	2
Task11	25	1.84	1.31	16	1.06	0.25	1
Task12	25	1.76	0.93	17	1.00	0.00	1
Total	**247**	**70.96**	**26.14**	**180**	**62.73**	**26.88**	**38**

Overall, this shows that participants had problems with using the system compared to the baseline in the first time period and only showed minor improvements after 8 weeks.

6.6.5 Questionnaire Analysis

The usability questionnaire was given to the participants at the end of each session. The total number of answers in each category, for each subjective question was calculated and is shown in Table 6.4. In the first session none of the participants Strongly Disagreed with all questions, however there was one participant Disagree in Q1 and Q3. The result shows that the majority of respondents were Agree and Strongly Agree in both sessions.

Table 6.4: Number of answers in each category of each subjective question in each session.

	Session 1			**Session 2**		
Category	Q1	Q2	Q3	Q1	Q2	Q3
Strongly Disagree	0	0	0	0	0	0
Disagree	1	0	1	0	0	0
Somewhat Disagree	1	2	1	1	0	1
Neither Agree nor Disagree	0	1	3	0	1	2
Somewhat Agree	8	2	6	3	1	4
Agree	9	9	8	4	5	3
Strongly Agree	6	11	6	9	10	7
Total number of participants	**25**	**25**	**25**	**17**	**17**	**17**

Overall, there was improvement in responses in the second session (see Table 6.5). In session 1 the modal response was agree for Q1 and Q3 and strongly agree for Q2. In session 2 the modal response was strongly agree for all questions. Thus, on average, the participants felt the usability, effectiveness and general support provided by the VLE was good, and there were no participants who were very unsatisfied. Moreover, the satisfaction of the time taken (Q2) has a lower SD in the second task, showing that there are less extreme values of dissatisfaction. However, there is a less significant increase with the level of online help, as both the means and SDs remain large, indicating that the scores given were similar after both sessions.

Table 6.5: The average and SD of the questionnaire in the two sessions

	Session 1				Session 2			
Questions	**N**	**Mean**	**Median**	**SD**	**N**	**Mean**	**Median**	**SD**
Q1	25	5.64	6	1.22	17	6.18	7	1.13
Q2	25	6.04	6	1.21	17	6.41	7	0.87
Q3	25	5.48	6	1.33	17	5.76	6	1.30

The average subjective reply for each participant for each session is shown in Table 6.6.

Table 6.6: The average subjective reply for each participant for the first session and the second session

Participants	**Mean Session 1**	**Mean Session 2**
P1	6.00	6.00
P2	3.67	5.67
P3	5.00	6.67
P4	6.67	4.67
P5	6.67	4.00
P6	4.00	7.00
P7	6.67	6.67
P8	6.33	6.00
P9	6.33	5.33
P10	6.67	7.00
P11	4.33	7.00
P12	5.67	7.00
P13	6.33	7.00
P14	7.00	7.00
P15	6.00	4.67
P16	4.33	6.33
P17	6.00	6.00
P18	5.33	-
P19	5.00	-
P20	6.33	-
P21	5.00	-
P22	6.67	-
P23	5.67	-
P24	5.33	-
P25	6.00	-

Comparing the results of the questionnaire with the results obtained by analysing the objective measures, it would appear that objective measures suggest that usability, particularly efficiency and learnability, were poor, whereas the subjective measures indicate that usability was good. This is investigated further in the following section.

6.6.6 Relationship Between Subjective and Objective Results

In order to explore the relationship between the subjective and objective results in more detail, we have calculated the average subjective reply for each participant from the questionnaire (shown in Table 6.6 above) for each session and then correlated this with each subject's weighted success rate (a measure that represents a combination of the multiple subjective measures).

The weighted success rate is calculated, using the data from the first session (i.e. tasks completed by all participants) and the time baseline for the task as the weight. This means that participants not only get a value of 1 or 0 for completing a task, but also get the value of the baseline time for the tasks. For example, consider the data for participant 1 in Appendix D Table D.3, which relates to all the tasks completed by participant 1 in session 1. The weighted completion rate is 66/69 = 0.96. In this calculation, 69 is the overall baseline sum and 66 represents the completed baseline sum. The overall baseline sum is the same for each participant, representing the total of all the baseline times for all 12 tasks. The completed baseline sum is different for each participant, representing only the total of the baseline times for tasks which the participant has completed.

This process was then applied to the other participants (see Table 6.7), so that comparisons could be made across participants (even though they did not all successfully complete the same tasks). For each participant the time weighted success rate for each session is shown in Appendix D Table D.1 and Table D.2.

Table 6.7: Time weighted success rate in the First and Second sessions

Participants	Baseline	Completed baseline sum	Weighted success rate session 1	Completed baseline sum	Weighted success rate session 2
P1	69	66	0.96	35	0.51
P2	69	47	0.68	49	0.71
P3	69	36	0.52	45	0.65
P4	69	53	0.77	69	1.00
P5	69	65	0.94	69	1.00
P6	69	56	0.81	69	1.00
P7	69	60	0.87	56	0.81
P8	69	64	0.93	69	1.00
P9	69	65	0.94	52	0.75
P10	69	69	1	56	0.81
P11	69	58	0.84	69	1.00
P12	69	66	0.96	69	1.00
P13	69	56	0.81	52	0.75
P14	69	49	0.71	49	0.71
P15	69	46	0.67	40	0.58
P16	69	52	0.75	36	0.52
P17	69	64	0.93	69	1.00
P18	69	46	0.67	-	-
P19	69	50	0.72	-	-
P20	69	47	0.68	-	-
P21	69	50	0.72	-	-
P22	69	58	0.84	-	-
P23	69	47	0.68	-	-
P24	69	37	0.54	-	-
P25	69	49	0.71	-	-
Average	-	-	0.79	-	0.81
Standard deviation	-	-	0.13	-	0.18

In order to determine the relationship between the subjective and objective results, the correlation was calculated between each participant mean response from the questionnaire and the weighted success rate, for each session. This is aimed at investigating whether or not the subjective response and objective results are consistent for individual subjects.

In the first session the correlation between the weighted success rate and the mean response from the questionnaire was positive, but small (0.37). This suggests that the assessment of usability was based primarily on the extent to which the participants were able to complete the

tasks irrespective of their difficulty. In the second session there was no significant correlation (-0.02). Clearly the usability assessment was not related to success rate and might have reflected the participants' experience using the system during the semester rather than their specific success on the given tasks. In this case, with computer science students, their assessments might be related to increased knowledge of how to build usable systems although it is a bit unlikely that 8 weeks of studying a computer science degree would change students' expectations for system usability (unless they had been taught about design for usability, which they had not at this point). Furthermore, their own experiences during the semester might have been more influential than completing the tasks. This again indicates that subjective assessments may conflict with objective measurement. Therefore, objective measurements are important because they can give insights into areas where the design might be improved. However, it is important to identify and to assess performance on all critical tasks.

We checked the relationship between the click baseline values and the time baseline values and it seems that they are very highly correlated (0.963). The participants' click scores and time scores also correlated with (0.807) in the first session and (0.590) in the second session. Therefore, we should get similar results for the analysis of the participants' time scores and the analysis of their click scores. Therefore, it does not matter very much which weight we choose but it is best to choose the weight that has greater variability, which is the baseline time score. Therefore, overall we found that the subjective response and objective results are not consistent for individual subjects.

6.7 Discussion

6.7.1 Summary of the results

This study aimed to assess the usability of a VLE by observing and measuring users' interactions with the system and compare the results with traditional subjective assessments of

usability. Although effectiveness (i.e. success rate) appeared satisfactory, even after two attempts and having been shown how to complete them all after session 1, some participants were unable to complete the tasks in session 2. Task 5 and Task 6 caused difficulties for a substantial proportion of participants in both sessions, and Task 9 caused a problem for about 30% of participants in each session. Although Task 5 which involves finding the opening hours for the library may not be considered critical, Task 6 which involves downloading the slides from a lecture and Task 9 which involves downloading practical work assignments and submitting the results are both extremely important tasks for students to master. Compared with the baseline, efficiency (i.e. time and number of clicks per completed task) was poor in both sessions although there was some improvement in session 2. In particular, Task 9 took much more time and more clicks than other tasks in both sessions

However, in contrast to the results of the objective assessment, the results of the questionnaire, suggested that on average, participants found usability and efficiency of the VLE acceptable, which suggests a disagreement between the two methods of assessment. This could be due to the fact that although several tasks caused problems for some participants, they overall felt the system was acceptable.

6.7.2 Consistency with other studies

Our results are consistent with the literature indicating the TAM variables perceived ease of use (PEU) and perceived usefulness (PU) are less likely to be correlated with actual usage than intention to use (Turner, Kitchenham, Brereton, Charters & Budgen, 2010). The results are also in agreement with the conclusion of Harrati et al. (2016), who found that that the SUS by itself is not adequate for evaluating the level of satisfaction and success of the system of an E-learning platform. These results suggest that, although usability is often assessed using subjective assessments, objective task analysis is also important. In particular, it can identify

tasks that are particularly difficult for users to perform even after some experience of using a system. Similarly, Oliver, Kostkova, & de Quincey (2009) found that when studying user satisfaction and usage of semantic web browsers found discrepancies between users' reports of what they did and their actual actions and suggested that mixed-method evaluation approaches are needed e.g. combining standard questionnaires, interviews and server log data.

Finally, this study is consistent with the outcomes from the result presented in Chapter Four, which investigated the overall usability of a VLE by using the SUS and free text responses. The results in Chapter four indicated that although the VLE usability is acceptable (SUS score of 62.52), a thematic analysis of comments revealed very negative views of the VLE as well as areas for improvement.

It seems from the results of this study, and the others mentioned above, that traditional subjective measures of usability are on their own not a reliable method for getting a consistent and accurate view of a system's usability. It is recommended therefore that usability testing should be performed using realistic tasks and a combination of subjective and objectives to determine a comprehensive view of how usable a system actually is, particularly on systems where users are expected to be able to just use the system without any training (which is a common problem with VLE's).

6.7.3 Limitations

This study has several limitations. First, this research was carried out on a small sample of the population with 25 participants and 17 participants in the second session. Furthermore, only students from the school Computing and Mathematic took part in the study and we would expect such students to be more computer literate than students in other schools which can make a difference when it comes to the evaluation of the use of online platforms (Thomas, King & Minocha, 2009). Also, this study was undertaken at a UK based institution and cannot

be extrapolated to other countries because the use of VLE's may be significantly different in different education systems. Finally, we have not performed any formal statistical tests of the effectiveness and efficiency measures for the reasons discussed in Section 5.1, but the availability of the baseline makes the results straightforward to interpret without such tests.

6.8 Conclusion

In this chapter, a new model of usability factors and measures by exploring how subjective and objective measures are related, applied to the usability of a popular VLE platform. It was found that the objective performance of students improved in most tasks between sessions but some students found it slightly difficult to use the VLE, even after eight weeks of exposure. Overall, the system has an acceptable level of efficiency (i.e. over 80% success rate), but compared with the baseline, effectiveness was poor in both sessions. It seems that some students found it difficult to complete specific tasks, which may to be due to problems with navigation or the visibility of features. In both sessions, the mean response for Q1, Q2 and Q3 was "Somewhat Agree" and "Agree" meaning that the users were generally satisfied with using the VLE. When comparing the results of the subjective questionnaire with the results obtained by analysing the objective measures, it would appear that the former indicates that the usability is reasonably good whereas the latter suggests that usability, particularly efficiency, was poor. This therefore has implications for the use of subjective questionnaires alone and how accurate user perceptions are of their own level of performance and satisfaction.

The novelty in this chapter is the proposed model that combines subjective and objective measures, the inclusion of an improvement metric where the experiment is repeated after the participants have had repeated natural exposure to the system and the use of a comparison baseline provided by a skilled user of the system to compare user performance.

In all cases, a good assessment of usability cannot be based on subjective assessment alone to avoid the issue of people saying something is good but struggling to use it. Task-based, objective usability measurement is therefore critical to formulate a true picture of system usability and has the added benefit of being able to identify specific usability issues. Future work could be focussed on how to deal with incomplete data using statistical techniques, as well as, measuring memorability based on actual usage of a VLE. The findings of this chapter addressed thesis objectives numbers 5 and 6 (To determine what are the most appropriate and effective methods for evaluating the usability of VLEs, and to investigate how usability attributes may change over time based on actual usage**).**

Chapter 7: Discussion

In this chapter, the findings of all of the studies described earlier will be discussed in relation to the research aims and questions (Chapter One, Section 1.2 and Section 1.3) and the existing literature.

7.1 Introduction

The overall aim of this thesis was to assess the usability of a VLE and identify the best methods for usability assessment. To achieve this aim, five research questions were formulated. To address RQ1 and RQ2, the usability of an E-learning system was investigated, which is discussed in Section 7.2. This section also presents the survey results and the thematic analysis of findings of the work undertaken to assess the usability of the VLE at the universities. To answer RQ3, an extension model of the TAM was developed, which is presented in Section 7.3. In address RQ4 and RQ5, work was undertaken to develop a novel model to assess the usability of the VLE and compare the results of the subjective and objective measures, which are presented in Section 7.4. Section 7.5 presents the thesis contributions and Section 7.6 discusses the implications of the research findings. The limitations of the research in this thesis are outlined in Section 7.7. The chapter concludes with a summary in Section 7.8. Recommendations to assess the usability of the VLE, along with suggestions for future work, are provided in Chapter Eight.

7.2 The Usability of E-learning

RQ1: How can the usability of a VLE used in higher education be measured?

RQ2: What are the important factors that influence the usability of the VLE in higher education?

An SMS was conducted to identify the usability issues and evaluation methods in the area of the usability of E-learning, tools that have been used, and questionnaires that are being used to evaluate the platforms. It provides an overview and guidance for scholars regarding the platforms tested, usability problems identified, and participants. This SMS established the need for an investigation into the usability of the E-learning platforms in higher education, which agreed with the recommendation of the mapping study published by Nakamura et al. (2017). However, the mapping study in Chapter Two has unique research questions and inclusion and exclusion criteria compared to the mapping study published by Nakamura et al. (2017), for example, RQ1 How can the usability of a VLE used in higher education be measured? and RQ2. What are the important factors that influence the usability of the VLE in higher education?

The results of this mapping study show that most studies mainly used questionnaires and were based on opinion rather than actual use, which confirmed the result of Plantak et al. (2010). The assessment based on actual use employing appropriate methods provides a comprehensive picture of the actual level of the usability of the platform. Furthermore, based on the SMS, the effectiveness, satisfaction and efficiency were the most important factors that have been investigated in recent years. Attitude, navigation, and information quality were more general problems identified regarding the usability of VLEs.

Surprisingly, evaluating the usability of VLE systems using a questionnaire with free text responses was only used previously in a few studies, as shown in the mapping study review (see Section 2.1). Therefore, in Chapter Four, the researchers evaluated the usability of the VLE platforms using both a subjective and an objective questionnaire. The results indicated that although the VLE usability is acceptable (SUS score of 62.52), a thematic analysis of comments revealed very negative views of the VLE as well as areas for improvement (Chapter

Four). Study one agreed with Chu et al.'s (2020) finding of an SUS score of 80.9, which is considered an 'excellent' level of usability; however, there was still some negative feedback. Conversely, it contradicts the finding of Larasati and Santoso (2017) who found similar results when comparing the SUS and interviews. The finding of the study presented in Chapter Four, which investigated the overall usability of a VLE by using the SUS and free text responses, and the outcomes in Chapter 6 are consistent. To overcome this issue, a model to evaluate the usability based on actual use was designed.

Harrati et al. (2016) and Olanrewaju and Omiola (2018) investigated the usability of the E-learning at university via a questionnaire, the outcome of which showed an average usability level of E-learning systems among users. Moreover, the SUS score is not sufficient on its own to evaluate the usability of an E-learning platform (Harrati et al., 2016). This research used both quantitative and qualitative research methods to evaluate the usability of the VLE and compared the result to the baseline. This enabled the researchers to obtain a comprehensive picture of the usability of the VLE to propose some useful recommendations for the VLE provider.

In general, it is difficult to assess usability by using the SUS alone, and a better and more accurate outcome can be achieved if usability is evaluated based on its attributes. Therefore, in the study outlined in Chapter Five, the researchers investigated some of the usability attributes independently with the TAM as some of the VLE users noted that they had not learned how to use it after three years, while others stated that they did not enjoy using it and they only use it as it is a part of their studies.

The outcome agreed with finding of the literature review and previous studies that full assessment of the VLE platforms is needed using both subjective and objective measures.

7.3 The Influence of Usability, Learnability and Perceived Enjoyment on Technology Acceptance

RQ3: What are the relationships between the common usability factors in the use of the VLE in higher education?

As discussed in Chapter Four, the VLE system has an acceptable usability level; however, the students identified a number of issues with the system, which means that usability is related to more than whether is the system working or not. Therefore, in Chapter Five, the researcher discussed the model built based on the TAM to evaluate the usability of the VLE systems and investigate whether usability, learnability and PE could be added to the TAM to determine their effect on usefulness and ease of use. As discussed in Chapter Five (Sections 5.1 and 5.2), the relationship between the original TAM factors was ignored as it has been investigated in a number of previous studies.

The main results were as follows:

a) Usability and PE have a statistically significant effect on students' PU of a VLE.
b) PE and learnability have a statistically significant effect on students' PEOU of a VLE.
c) Usability and learnability do not have a statistically significant effect on students' PEOU of a VLE.

The above results are consistent with the literature, which indicated that the TAM variables PEOU and PU are less likely to be correlated with actual usage than intention to use (Turner et al., 2010). Furthermore, the results suggest that when individuals feel that the system is usable and learnable as well as enjoyable and useful, their intention to use the VLE at universities will increase. However, usability and learnability do not have a statistically significant effect on students' PEOU of a VLE.

The proposed model explained 19% of the total variance in the students' PU and 39% of the total variance in the students' PEOU. These findings are consistent with earlier TAM-related studies such as that of Chiu Hsu, Sun, Lin, & Sun (2005), who discovered that perceived usability had significant effects on satisfaction and could explain the significant variation in satisfaction with E-learning, as their model explained 68% and 48% of the variability in the intention to use E-learning. Poelmans et al. (2008) also found perceived usability to be a strong determinant of cognitive absorption, satisfaction, perceived usefulness and perceived ease of use. Moreover, according to Hayashi, Chen, Ryan, and Wu (2004) and consistent with the result of this study, usability and PE had the strongest effect on PU. Similarly, the models of Purnomo and Lee (2013) and Elkaseh et al. (2016) explained 19% of the variability of the intention to use E-learning.

The results of this study show that PE significantly affects students' PU and PEOU of the VLE systems at universities. This finding is supported by and in accordance with the findings of Shyu and Huang (2011) and Elkaseh et al. (2016), who found that PE had a significant impact on the ease of use of E-learning.

The above result confirmed that usability and learnability are important in VLE acceptance. As discussed in Chapter Four, although an acceptable level of usability was found, there was negative free text feedback from the students. Therefore, this difference needed to be investigated in more detail and led to the creation of a novel method for assessing those factors subjectively and objectively, which provided a better indicator of the level of usability.

7.4 Usability Evaluation of Virtual Learning Environments Using Subjective and Objective Measures

RQ4: How do the different methods for measuring usability differ and is there a systematic difference between the output of different methods used to assess VLE usability?

RQ5: Do the usability attributes change over time based on actual usage?

The researchers built a model based on both subjective and objective measures and compared the findings, and then compared the result of objective measures to the baseline set by skilled users. The outcome aligned with the literature review and previous studies showing that full assessment of the VLE platforms is needed using both subjective and objective measures.

Although the task success rate was relatively high (i.e. 82.3% in session 1), an average participant would have taken 3.6 times longer to complete the set of tasks than an experienced skilled user. Furthermore, task time, clicks and success rate had improved only marginally at the end of the semester. When compared to the analysis of the subjective measures, however, participants stated that they were satisfied with the usability of the system, contradicting the analysis of the objective measures.

From the results of this study and the others mentioned above, it seems that traditional subjective measures of usability alone are not a reliable method for obtaining a consistent and accurate view of a system's usability. This is consistent with the findings of the study in Chapter 4 and those of Harrati et al. (2016), demonstrated using the SUS alone is not adequate for evaluating the level of satisfaction and success of the system of an E-learning platform as this can conceal significant issues. Usability assessment should therefore be based on actual performance against a defined baseline and not solely on subjective assessments.

Bowers and Snyder (1990), Hornbæk (2006), Downey et al. (2007), Law et al. (2007), Tamir et al. (2008), Pretorius and van Biljon (2010) and Torun and Tekedere (2015) evaluated usability by asking users to complete tasks on the platform rapidly and using the completion time and the number of clicks needed to complete a task (with users who had not received training prior to the session). This thesis evaluated the usability of the VLE in a unique way by using the completion time and counting the number of clicks users needed to complete a task over two sessions in parallel with a questionnaire, and then compared their performance to that of a skilled user (baseline). This enabled us to gain a more detailed understanding of how usable the VLE is.

7.5 Contributions of Research

The research reported in this thesis makes a number of contributions to knowledge in the field of usability, usability testing, and the design and evaluation of VLE systems.

The overarching contribution of this thesis is that by using several different approaches, the researchers have shown that usability evaluation techniques that are currently used have weaknesses and that researchers cannot rely on the use of one method alone to obtain a true picture of what users think and their experience of a VLE.

Furthermore, based on the results and findings of this thesis, it is important to note that usability is mostly about ensuring how easy to use the system is, the functionality and whether it is reliable or not, rather than engagement and the effort and time needed to perform a specific task.

In addition, there is a lack of awareness of the specific usability issues with the VLEs, which may be resolved by discussing these issues with the actual users of the VLE platform, students

and staff, who could help the universities to have a more usable platform, which would help the students to engage with the systems.

Moreover, using objectives measures is a reliable way of assessing the VLEs rather than using only subjective measures, which show that overall, the students are satisfied, and this can have a negative impact on improvement of completing a task in a good time if neglected.

Another important finding was that the concept of usability seems to be understood in a very narrow and limited sense as it only concerns basic functionality and ensuring reliability and efficiency at most. It was not common to find improvement after a few weeks of using the VLEs.

Furthermore, the importance of usability has been emphasised in several places in this chapter and the importance of evaluating usability has been highlighted several times in this thesis. Novak et al. (2010) considered usability as a very important factor that could affect VLE platforms in particular.

The following are specific contributions made by each chapter.

- Abuhlfaia and de Quincey's (2018) "The usability of E-learning platforms in higher education: A systematic mapping study" was published in the Proceedings of the 32nd International BCS Human–Computer Interaction Conference (see Chapter Two). The SMS investigated the current empirical work that relates to the usability of E-learning systems in higher education. It provided a clear view of the methods used currently to evaluate platforms and specific usability issues, for example, satisfaction and efficiency. The results showed that it would be useful to add other usability factors, such as attitude and navigation, to the standard usability attributes and use a combination of assessment methods, such as focus groups and questionnaires. The

results also highlighted that few studies have focused on the effectiveness of the assessment techniques themselves.

- Abuhlfaia and de Quincey's (2019) "Evaluating the usability of an E-learning platform within higher education from a student perspective" was published in the Proceedings of the 2019 3rd International Conference on Education and E-Learning (see Chapter Four). The results of this large-scale usability evaluation study with 101 students showed that there is disparity between the level of usability indicated by the SUS score and free text comments provided by respondents. This questions the validity of the SUS as the SUS score may not give a complete picture of the usability of a system in relation to user comments from the feedback. A number of recommendations were then determined to improve the design of the interface and the usability of the system, such as the need for staff training on how to design a module in a VLE with relevant and important materials.
- Chapter Five confirmed that the TAM could be improved for evaluating the ease of adoption of E-learning systems by adding usability and learnability independently with PE. This was achieved by collecting the responses of a large number of students (162). The results showed that learnability and PE have an impact on PEOU and that the usability and PE of the VLE directly affect the students' PU of using the VLE platform. However, usability and learnability do not have an effect on PE, which means that even if systems are not considered as usable, they are still perceived as enjoyable.
- The final contribution is the confirmation of previous findings by using a novel method for assessing usability both subjectively and objectively based on actual use of a VLE in two sessions. The results showed that there is a mismatch between what people say about their experience and what they actually do when using a VLE, that is,

participants' responses to the questions (Lewis, 1994) indicated that they were satisfied with the usability of the system, which contradicts the results of the objective measures. A further contribution of this study is the creation of a novel technique for creating a baseline measure for comparison.

The overarching contribution of this thesis is that by using several different approaches, the researchers have shown that usability evaluation techniques used currently have weaknesses and that researchers cannot rely on the use of one method alone to obtain a true picture of what users think and their experience of using a VLE.

7.6 Thesis Implications

This section summarises the implications of the results of this thesis.

7.6.1 Implications of the Systematic Mapping Study

The SMS discussed in Chapter Two investigated the empirical studies on the usability of E-learning. Although this is not the first mapping study in this area, it is unique in terms of the search strategy and inclusion and exclusion criteria in the search questions. The SMS found that few studies used objective methods and there is less focus on some usability factors, for instance, learnability, memorability and errors. The result provides a clear picture of the current work on the usability of E-learning. This helped this thesis to make a unique contribution to this area and it will help future researchers to improve the usability of E-learning platforms and the evaluation of their usability. Furthermore, VLE providers and designers can benefit from the SMS as it provides a clear overview of the main issues with the VLE systems and how they can address these issues (see Chapter Two).

7.6.2 Implication of the Evaluation of VLEs

The research studies discussed in Chapter Four and Chapter Six proved that using only a questionnaire sometimes cannot provide the full picture of how usable the system is, as using a questionnaire can miss tacit and semi-tacit knowledge (Rugg & Petre, 2007). As previous research findings show, E-learning programs may fail due to a lack of technological support (Al-Harbi, 2014; Selim, 2007). This work has also provided an overview of how students perceive the usability of a VLE, which may affect how they accept this technology. Some recommendations have been made to enhance the usability of the VLEs (see Chapter Four and Chapter Six).

The SUS questionnaire (see Appendix C.3) and the pre-defined tasks and short questions in Sections 6.4.2 and 6.4.5 were suitably worded and appropriate for extracting the required information, such as time needed and number of mouse clicks. The use of the novel model (Figure 6.1) provides a full picture of how usable the system is as the researchers collected the data using the subjective and objective measures and then compared the results. Therefore, it is important to use objective measures along with subjective measures and not rely solely on the SUS. Developers need to combine questionnaires, observation and free texts to obtain an overall view of usability. Moreover, the results of objective measures can be compared to the baseline of a skilled user.

This combination of measures can be used with other educational institutions and commercial companies to evaluate the systems based on the actual use after defining the main tasks that the users would generally need to complete. This approach can also be used by other scholars if they have limited time as it is has the advantage of being able to compare the different results and attempting to avoid potential bias that comes from the use of subjective measures.

7.6.3 Theoretical Implication

The interesting theoretical implication of the model is the extension of the original TAM by adding usability attributes. The results in Chapter Five confirmed that the TAM could be improved for evaluating the ease of adoption of E-learning systems by adding usability and learnability independently. They showed that usability and PE directly affect the PU of using the VLE platform, and that learnability and PE have an impact on PEOU. This aligns with Binyamin, Rutter and Smith's (2019) finding that PEOU is affected by a number of factors, such as system learnability and system navigation. However, usability and learnability do not have an effect on PE, which means that the even if the systems are not usable, they are still enjoyable. The model does not explain the high percentage of variation in usefulness and ease of use, however. This means that external factors do not explain the whole picture.

This research makes a contribution to the field as it explored the impact of usability and learnability independently on acceptance of a VLE, whereas previous research explored the impact of usability on satisfaction with a VLE (e.g. Chiu et al., 2005; Poelmans et al., 2008; Roca et al., 2006). Furthermore, this thesis has clarified that usability has a positive effect, whereas Lin's (2013) work found that the correlation between PU and usability was unclear since the TAM and the usability test had two dissimilar aspects. Researchers can use the extended version of the TAM and apply it to other E-learning platforms, E-banking systems and E-commerce systems.

7.7 Limitations

The limitations of this thesis are divided into two parts: the mapping study limitations and the experimental limitations. The limitations of the mapping study relate to misclassification, publication bias, selection bias, and inexactness in data extraction. Selection bias refers to the misrepresentation of statistical analysis due to criteria that have been used in the selection of

published papers (Fernandez et al., 2011). To attempt to mitigate this, detailed inclusion and exclusion criteria were determined and validated by the researcher. A related issue is that during data extraction, it is possible that information is overlooked or misclassified by reviewers. To mitigate this, the extraction and classification of the studies were conducted by the researcher, with cross-checking by the researcher and an expert in SMS on ten papers until the protocol and extraction process were agreed upon and standardised.

There are a number of experimental limitations in this thesis. First, the demographic of the respondents is not fully representative of the student body at the university. There were significantly more female participants than male participants in the studies detailed in Chapter Four and Chapter Five, while in the study described in Chapter Six there were more males then females. Moreover, most of the students were aged between 18 and 27 years with little representation of mature students in all the studies. Furthermore, there was not equal participation from all the university schools, with some schools being represented by a single student. Finally, this research was undertaken at a UK-based institution and cannot be extrapolated to other countries as the results may be significantly different when using students from different societies and education systems.

The main challenges of conducting research with students related to their availability at appropriate times and the level of experience required. In the first observation session discussed in Chapter 6, the selection criterion was students with limited experience of using a VLE. There was also the subsequent issue of recruiting the same students for the second session a few weeks later (when they had gained more experience in using the VLE), and it was difficult to obtain a representative sample.

For the observation study (Usability Evaluation of Virtual Learning Environments Using Subjective and Objective Measures), the sample population consisted of undergraduate

students from the School of Computing and Mathematics, and the researchers would expect such students to be more computer-literate than students in other schools. This potentially limits the generalisation of the study among its various users.

Another limitation is that the observation study was carried out on a small sample with 25 participants in the first session and 17 participants in the second session. Finally, the researchers did not perform any formal statistical tests of the effectiveness and efficiency measures for the reasons discussed in Section 5.1; however, the availability of the baseline makes it easy to interpret the results without such tests.

7.8 Conclusion and Summary

This chapter has brought all the findings of the work undertaken together and attempted to answer the research questions. In addition, the research contributions have been outlined and the research limitations have been highlighted. The following chapter provides a final summary of the work and conclusions, as well as recommendations on how to evaluate the usability of the VLE platforms in higher education and suggestions for future work.

Chapter 8 Conclusions and Recommendations

8.1 Summary of the Research

The purpose of this research was to evaluate the usability of the VLE platforms in higher education and identify the best methods to use for evaluating such platforms to ascertain a more representative usability level.

In the early stages of this project, a review of the literature (SMS) was conducted to identify and classify the existing empirical studies on the usability of E-learning, mainly the usability problems, methods used to test usability, platform tested, and questionnaires used. The SMS identified 61 articles with related studies. However, it was found that the majority of the papers mainly used questionnaires as the main method to evaluate the platforms and lacked important details on the tools used to analyse the collected data. Furthermore, little attention was paid to the learnability, memorability and errors in these studies.

The findings of the mapping study provided the motivation for conducting studies assessing the usability of VLE platforms using a range of quantitative and qualitative methods, including standard questionnaires, adapted questionnaires and observation using both quantitative and qualitative methods, based on actual usage from the user perspective.

The first study gathered information from the students using a questionnaire that included open-ended and close-ended questions based on a pre-existing instrument (SUS). The results showed that although the usability scores were acceptable, the free text feedback from users was mainly negative, which may affect the users' acceptance of using a VLE. They also showed that there are potential issues related to relying on the SUS alone.

Following the initial overview of usability, a unique contribution was made by extending the TAM by adding usability and learnability factors independently to the original model along with perceived enjoyment. Furthermore, how these factors affect the perceived usefulness and perceived ease of use of the VLE was investigated. It was found that usability and perceived enjoyment had a significant effect on perceived usefulness, that learnability and perceived enjoyment affected the perceived ease of use, and that usability and learnability seemed to have no effect on perceived enjoyment. Therefore, adding usability, learnability and perceived enjoyment can potentially improve the TAM.

A novel method was then developed to assess usability both subjectively and objectively. A short questionnaire and pre-defined tasks were used to measure how usable the system was, which allowed the researchers to extract the required data, the time needed to complete the tasks and number of mouse clicks to analyse the usability and measure any improvement after a few weeks. This result was then compared to the baseline of a skilled user. Finally, the overall response from the participants was compared with their weighted success rate of completing the tasks. The result shows that although the participants were satisfied with the VLE based on the questionnaire responses, they were not able to complete important tasks in the two sessions and when compared to the baseline, they took more time and clicks to complete the tasks. Therefore, the conclusion is that using subjective measures alone to assess the usability of a complex system can conceal significant issues.

The overall findings show that the usability and its attributes are very important considerations when users engage with a VLE and affect their ability to use it. Improving the learnability and usability of any platform is very important so that users can focus on the learning activities themselves rather than wasting time trying to figure out how to use the platform.

Comparing and contrasting the results of quantitative and qualitative methods highlights that there is currently over-reliance on questionnaires as a method. The novel methods and model developed for this thesis provide a more detailed picture of how usable a system is. The studies in this thesis therefore provide interesting results not only on the usability of VLE platforms themselves, but also on the methods needed to evaluate their usability. It is hoped that this work will provide a better understanding of the usability of the VLEs in higher education for a variety of different stakeholders.

8.2 Recommendations

The research makes the following recommendations based on the findings and experience in the different studies:

- Usability testing should be performed using realistic tasks and a combination of subjective and objective measures should be used to gain a comprehensive view of how usable a system actually is, particularly for systems where users are expected to be able to use the system without any training (which is a common problem with VLEs).
- Task scenarios should be based on the main activities that the users would usually need to carry out on the system.
- The developers and VLE platform providers should run usability testing during the actual design and development of the system by asking students for feedback on the platform, as highlighted by Macaulay (1996).
- Universities should provide training to their staff on how best to use the VLE to avoid common issues, such as students not being able to find resources.
- Designing a usability test is difficult; however, it would require more time and money to perform testing using methods such as eye tracking.

- Considering adopting objective methods to collect data is important as it is not an easy task to analyse the data if tasks have not been completed by a number of users, and therefore a complete plan is required.
- Reassessment of VLE systems is important as users and technologies change over time.
- Developers need to be aware of the importance of usability and its aspects. They should increase their awareness and knowledge of such important issues, as confirmed by Larman (2002) and Alotaibi (2015).
- When using observation over more than one session, some respondents will not come back to perform the tasks in the second session. To resolve this problem, the sample size needs to be increased.

To help the VLE team at Keele university to make improvements and update the current version of the VLE, the student feedback was shared with them. It is not possible to identify why these suggestions were not implemented but the likelihood is that some of these are fundamental issues with the underlying platform itself (Blackboard) such as the lack of search functionality. For future work, a written summary of the recommendations that is easy to understand will be produced with an emphasis of stating why it is important to update the VLE based on the findings of this research and the benefits to organisations who comply with users' needs (de Luca, 2020; Penny & Child Bereavement Network, 2006).

8.3 Suggestions for Future Research

Although this study adopted a positive approach in reviewing previous studies on the usability of E-learning, there are several limitations and some opportunities for future work, which are outlined below:

- This thesis identifies and suggests a number of future research studies that should be conducted to consolidate the perceived interaction, memorability and effectiveness of using the VLE platforms. This can be done using the log file of the systems and comparing it with the actual use by employing the model provided in Chapter Six.
- Future investigations could evaluate the usability of the VLEs at universities in other countries and cultures.
- This study focused only on students at a university. It would be interesting to conduct further studies with users with learning difficulties, administrators and lecturers to determine whether they have the same perceptions of using the VLEs in terms of usability.
- In addition, further studies could include other types of universities, such as open universities and non-higher education institutions, to ascertain whether there are any differences between the perceptions and attitudes of people in private, public and open universities.
- The researchers could use the original TAM or the extended version of the TAM and apply it to other E-learning platforms, such as Moodle, Massive Open Online Courses, E-banking systems and E-commerce systems.
- In the future, researchers could investigate the statistical problem, that is, handling incomplete data, in a replicated measures experiment where the users failed to complete the tasks.
- Qualitative research could be carried out by conducting interviews with students, lecturers and administrative staff to determine the effect of usability on the perceived ease of use and perceived usefulness of the VLE platforms at the universities.

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Appendix

Appendix Ethical Approval

Appendix A.1: Email Invitation Sent to Participants

Dear all,
My name is Khaled Abuhlfaia, I am a doctoral student in the School of Computing and Mathematics at Keele University and am conducting research into the quality of e-learning in universities. This online study seeks to understand users' experiences of the Keele Learning Environment (KLE), and their concerns about using the system in terms of usability.

Below are the links to the Participant Information Sheet, which provides more information about the study and the Consent Form and Questionnaire.

- Participant Information sheet

- Consent Form and Questionnaire

If you would like to participate please read the Participant Information Sheet carefully, complete the online Consent Form and then a short Questionnaire.

Many thanks for your assistance with this work.

Best wishes,

Khaled

Appendix A.2: Information Sheet

Study Title: *Factors Affecting the Quality of E-Learning in Universities; The Importance of Usability.*

Invitation

You are being invited to consider taking part in the research study Factors Affecting the Quality of E-Learning in Universities; The Importance of Usability. This project is being undertaken by Khaled Abuhlfaia, a PhD student in the School of Computing and Mathematics, under the supervision of Dr Ed de Quincey and Dr Theocharis Kyriacou.

Before you decide whether or not you wish to take part, it is important for you to understand why this research is being done and what it will involve. Please take time to read this information carefully and discuss it with friends and relatives if you wish. Ask us if there is anything that is unclear or if you would like more information.

Aims of the Research

The study seeks to understand users' experiences of the Keele Learning Environment (KLE), and their issues with using the system. The study will evaluate the use of KLE system in terms of usability. The study will initially be conducted online and all information will be provided by email and hard copy if needed.

This study will be conducted at Keele University as a part of my doctoral research.

Why have I been invited?

You have been invited to take part in this study as you are a student at Keele University and have used or have had exposure to the KLE. All participants are to be recruited at Keele University. To take part in this study:

1. **You must be aged 18 and above.**
2. **You must study at Keele University.**
3. **You must have used or had exposure to the KLE.**
4. **You must indicate your consent by tick the appropriate box on the consent form provided.**

Do I have to take part?

You are free to decide whether you wish to take part or not. If you do decide to take part you will be asked to respond to me by email. When I have completed the study I will produce a summary of the findings which I will be more than happy to send you if you wish. Participating in this study is completely voluntary. Your decision to participate will not affect your current or future relationship with the researchers or anyone else at Keele University or any department to which you may belong. Once you submit your response, you will not be able to withdraw it from this study, as your responses are anonymous. If required, a member of the research team will answer any questions or concerns.

What will happen if I take part?

This study intends to gather impressions and preferences about the usability of the Keele Learning Environment (KLE). You will be asked some general demographic questions and then asked to indicate your levels of agreement with a number of different statements relating to the KLE. The main survey questionnaire will take 30 minutes of your time to fill and submit.

What are the benefits (if any) of taking part?

Participation will provide an insight into research at Keele. Participation will not, however, advantage or disadvantage your studies and participation is wholly voluntary.

What are the risks (if any) of taking part?

There are no known potential risks or harm associated with your participating in this study beyond those of everyday life.

How will information about me be used?

By giving your consent, you allow the researcher to collect ~~personal~~ information about your expertise with using KLE for the purposes of this research study. Your information will only be used for the purposes mentioned in this participant information statement. Your participation in this study will be saved securely. Study results may be published.

Who will have access to information about me?

The researcher will adhere to Keele University guidelines on data protection to guarantee the confidentiality of ~~personal~~ the collected data. In all reports coming out of this research, you will be referred to as Participant 1, Participant 2 etc. Your real name, or anything that could identify you personally will not be collected in this study;. Only the research team will have access to the data collected from the questionnaires. All data will be stored on the researcher's personal desktop computer at Keele University and the file will be password protected. The personal computer itself is password protected using the University's Network Login. All electronic data will be disposed of, in accordance with Keele University IT protocols, 4 years after the study.

We are constrained by current legislation over matters such as privacy, confidentiality, data protection and human rights, therefore offers of confidentiality may sometimes be overridden by law.

Who is funding and organising the research?

This project research is funded by the Libyan Cultural Attache'.

What if there is a problem?

If you have any concerns about any aspect of this study, you may wish to speak to the researcher who will do his best to answer your questions. Please contact Khaled Abuhlfaia on **k.m.abuhlfaia@keele.ac.uk** Tel: **+44 (0)1782 734899**. Alternatively, if you do not wish to contact the researcher you may contact the lead supervisor, Dr Ed de Quincey on **e.de.quincey@keele.ac.uk** Tel**: +44(0)1782734090.**

If you remain unhappy about the research and/or wish to raise a complaint about any aspect of the way that you have been approached or treated during the course of the study please write to Nicola Leighton who is the University's contact for complaints regarding research at the following address:-

Nicola Leighton

Research Governance Officer

Directorate of Engagement and Partnerships

IC2 Building

Keele University

ST5 5NH

E-mail: n.leighton@ keele.ac.uk

Tel: 01782 733306

Contact for further information

1. Khaled Abuhlfaia

School of Computing and Mathematics

Keele University

Keele, Staffordshire

ST5 5BG

UK

Email: k.m.abuhlfaia@keele.ac.uk

Tel: +44 (0)1782 734899

2. Dr Ed de Quincey

Senior Lecturer of Computer Science and Informatics

Undergraduate & Postgraduate Course Director

School of Computing and Mathematics

Keele University

Keele, Staffordshire

ST5 5BG

UK

Tel. +44 (0)1782734090

Fax. +44-1782-734268

E-mail: e.de.quincey@keele.ac.uk

Appendix A.3: Online Consent Form

Title of Project: Factors Affecting the Quality of E-Learning in Universities; The Importance of Usability.

Name and contact details of Principal Investigator: Khaled Abuhlfaia, School of Computing and Mathematics, Keele University, Keele, Staffordshire, ST55BG, UK, Tel: +44 (0)1782 734899, e-mail: k.m.abuhlfaia@keele.ac.uk.

The following are the consent form statements:

1. I confirm that I have read and understood the information sheet dated 24/11/2017 (version no 1.3) for the above study and have had the opportunity to ask questions.*

2. I understand that my participation is voluntary and that I am not free to withdraw after I submit my respond, as this survey is anonymous.*

3. I agree to take part in this study.*

4. I agree for my quotes to be used.*

Clicking on the "agree" button below indicates that you agree with the above statements. If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button.

* agree
* Disagree

Appendix A.4: Ethical Approval Confirmation First Letter

Keele UNIVERSITY

30/11/2017

Dear Khaled

PI: Khaled Mohamed O Abuhlfaia
Title: Factors Affecting the Quality of E-Learning In Universities; The Importance of Usability
Ref: ERP3123

Thank you for submitting your revised application for review. The revised proposal was reviewed by the Panel Chair and approved by Chair's actions. I am pleased to inform you that your application has now been approved by the Ethics Review Panel.

If the fieldwork goes beyond the date stated in your application, or there are any amendments to your study you must submit an 'application to amend study' form to the ERP administrator at research.governance@keele.ac.uk. This form is available via http://www.keele.ac.uk/researchsupport/researchethics/

If you have any queries please do not hesitate to contact me, in writing, via the ERP administrator, at research.governance@keele.ac.uk stating **ERP3123** in the subject line of the e-mail.

Yours sincerely
PP.

Dr Valerie Ball
Chair – Ethical Review Panel

Keele UNIVERSITY

15th November 2018

Dear Khaled

PI: Khaled Mohamed O Abuhlfaia
Title: Factors Affecting the Quality of E-Learning In Universities; The Importance of Usability
Ref: ERP3123

Thank you for your request to amend your study.

I am pleased to inform you that your request, received on 8th November 2018 has been approved by the Ethical Review Panel.

If the fieldwork goes beyond the date stated or there are any other amendments to your study you must submit an 'application to amend study' form to the ERP administrator at research.governance@keele.ac.uk stating **ERP3123** in the subject line of the e-mail. This form is available via http://www.keele.ac.uk/researchsupport/researchethics/

If you have any queries, please do not hesitate to contact me.

Yours sincerely
PP.

Val Ball
Chair – Ethical Review Panel

Appendix A.5: Invitation to Participate

Dear Student,

My name is Khaled Abuhlfaia, I am a doctoral student in the school of Computing and Mathematics at Keele University. I am conducting research about the factors affecting the quality of e-Learning in universities; the importance of usability.

Below are the links to the Participant Information Sheet, which provides more information about the study and the Consent/Registration Form to participate in this study.

- Information Sheet Link

- Consent/Registration Form Link

The study will be conducted in the Knuth Lab 113 and all information will be provided by email. Please note that this study will be for two sessions, the first one will be in the first two weeks at the beginning of the semester and the second session will be after six to eight weeks. All students will receive an Amazon voucher of £20 if they attend **both sessions**, which will be conducted in the School of Computing and Mathematics at Keele University. Each session will take around 20 to 40 minutes dependent on the time needed to complete the tasks.

The study seeks to understand users' experiences of the Keele Learning Environment (KLE), and investigating how the error, memorability and learnability of an e-learning platform change during the running of a module. We are also interested in any general concerns students have about using the KLE in terms of usability.

You are invited to participate in the research study and I would appreciate any assistance you can offer, although you are under no obligation to do so. The study will take place between 01/09/2018 and 15/12/2019.

Best wishes,

Khaled

Appendix A.6: Information Sheet

Study Title: *Factors Affecting the Quality of E-Learning in Universities; The Importance of Usability.*

Invitation

You are being invited to consider taking part in the research study "Factors Affecting the Quality of E-Learning in Universities; The Importance of Usability". This project is being undertaken by Khaled Abuhlfaia, a PhD student in the School of Computing and Mathematics, under the supervision of Dr Ed de Quincey and Dr Theocharis Kyriacou.

Before you decide whether or not you wish to take part, it is important for you to understand why this research is being done and what it will involve. Please take time to read this information carefully and discuss it with friends and relatives if you wish. Ask us if there is anything that is unclear or if you would like more information.

Aims of the Research

The study seeks to understand users' experiences of the Keele Learning Environment (KLE), and any general concerns students have about using the KLE in terms of usability. The study will evaluate the use of KLE system in terms of usability, all information will be provided by email and hard copy if needed. The study will initially be conducted in the School of Computing and Mathematics as a part of my doctoral research.

Usability is a quality attribute that assesses how easy user interfaces are to use. This study focusses on 3 quality components of Usability. In the first session (held in Week 1 or 2) our aim is to test issues related to Learnability and Errors and the second session (held in Week 6 to 8) aims to evaluate Memorability.

1. *Learnability: How easy is it for users to accomplish basic tasks the first time they encounter the design?*
   In order to measure learnability we will be investigating whether students can complete a set of simple tasks (completion rate).
2. *Errors: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?*
   To measure error rates, we need to know how many times students need to "click" on the KLE before they can find the feature that they need to complete task.
3. *Memorability: When users return to the design after a period of not using it, how easily can they reestablish proficiency?*
   Memorability will be measured over two sessions (one at the start of the semester and the second one after six to eight weeks), using the same set of tasks and recording the time on task and completion rate.

Why have I been invited?

You have been invited to take part in this study as you are a first year student at Keele University. All participants are to be recruited at Keele University and to take part in this study you have to meet the following criteria:

1. **Aged 18 and above.**
2. **First year undergraduate students in Computer Science from the School of Computing and Mathematics at Keele University.**

3. **You must agree and sign the Consent/Registration form provided before taking part in the study.**

4. **Agree to attend the two sessions.**

Do I have to take part?

You are free to decide whether you wish to take part or not. If you do decide to take part you will be asked to please respond to me by email so that I know you are interested. When I have completed the study I will produce a summary of the findings which I will be more than happy to send you if you wish. Participating in this study is completely voluntary. Your decision to participate will not affect your current or future relationship with the researchers or anyone else at Keele University or any department to which you may belong. This study is not part of your degree programme and in no way contributes to it. You are free to withdraw from this study at any time and without giving reasons. If required, a member of the research team will go answer any questions or concerns.

If you wish to withdraw your data, you must make a request directly to one of the research team (in writing or verbally) within 14 days of the session. All data related to your participation will be destroyed and deleted from all media.

If a participant withdraws their data or leaves or fails to attend to the observation session, they will not be eligible for payment for the parts of the research in which they have already participated.

What will happen if I take part?

If you meet the eligibility requirements mentioned above you will need to go through the following steps:

1. Complete the Consent/Registration Form (link will be added here)
2. You will then be contacted by the researcher to book a suitable session time.

3. On the day of the session (held in the Knuth Lab 113), you will be given a set of tasks to perform using the KLE. Each session will take around 20 to 40 minutes dependent on the time needed to complete the task. The session will be recorded using screen capture software and the basic usage tracking that is part of the KLE. You will then be asked to complete a short questionnaire about the session.

What are the benefits (if any) of taking part?

All participants take part in the study in **both sessions** will get £20 Amazon voucher.

What are the risks (if any) of taking part?

There are no known potential risks or harm associated with your participating in this study beyond those of everyday working.

How will information about me be used?

By giving your consent, you allow the researcher to collect personal information about you for the purposes of this research study. The personal information that will be collected is your university email address (to add you to the relevant modules on the KLE) and your general usage data on the KLE for the 2 sessions and on computing modules in the intervening weeks e.g. click data and the time taken to complete the tasks. Your information will only be used for the purposes mentioned in this participant

information statement. Your information will be saved securely and all your personal information will be kept strictly confidential, except as required by law. Study results may be published, but you will not be individually identifiable in these publications.

Who will have access to information about me?

The researcher will adhere to Keele University guidelines on data protection to guarantee the confidentiality of personal data. In all reports coming out of this research, you will be referred to as Participant 1, participant 2 etc. Your real name, or anything that could identify you personally, will not be used in any written material. Only the research team will have access to any personal data from the recorded. All data will be stored on the researcher's personal desktop computer at Keele University and the file will be password protected. The personal computer itself is password protected using the University's Network Login. All electronic data will be disposed of, in accordance with Keele University IT protocols, 4 years after the study.

We are constrained by current legislation over matters such as privacy, confidentiality, data protection and human rights, therefore offers of confidentiality may sometimes be overridden by law.

Who is funding and organising the research?

This project research is funded by the Libyan Cultural Attache'.

What if there is a problem?

If you have any concerns about any aspect of this study, you may wish to speak to the researcher who will do his best to answer your questions. Please contact Khaled Abuhlfaia on **k.m.abuhlfaia@keele.ac.uk** Tel: **+44 (0)1782 734899**. Alternatively, if you do not wish to contact the researcher you may contact the lead supervisor, Dr Ed de Quincey on **e.de.quincey@keele.ac.uk** Tel**: +44(0)1782734090.**

If you remain unhappy about the research and/or wish to raise a complaint about any aspect of the way that you have been approached or treated during the course of the study please write to Nicola Leighton who is the University's contact for complaints regarding research at the following address:-

Research Integrity Team

Directorate of Research, Innovation and Engagement

IC2 Building, Keele University, ST5 5NE

Email: research.governance@keele.ac.uk

Tel: 01782 733371

Contact for further information

3. **Khaled Abuhlfaia**

School of Computing and Mathematics

Keele University

Keele, Staffordshire

ST5 5BG

UK

Email: k.m.abuhlfaia@keele.ac.uk

Tel: +44 (0)1782 734899

4. **Dr Ed de Quincey**

Senior Lecturer of Computer Science and Informatics

Undergraduate & Postgraduate Course Director

School of Computing and Mathematics

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UK

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E-mail: e.de.quincey@keele.ac.uk

Appendix A.7: Consent/ Registration Form

Title of Project: *Factors Affecting the Quality of E-Learning in Universities; The Importance of Usability.*

Name and contact details of Principal Investigator: *Khaled Abuhlfaia, School of Computing and Mathematics, Keele University, Keele, Staffordshire, ST55BG, UK, Tel:* +44 (0)1782 734899*, e-mail:* k.m.abuhlfaia@keele.ac.uk.

1. confirm that I have read and understood the information sheet dated 26/06/2018 (version no 1.0) for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw from the study up to 14 days from the date of each observation session and this will not affect your legal rights.
3. I agree to take part in this study.
4. I agree to be contacted about possible participation in future research project.
5. I agree to for my usage logs for the following modules Programming I - Programming Fundamentals; Fundamentals of Computing; and the Usability of the KLE 1 or 2 to be used.
6. I agree for my quotes to be used.

I agree with the above statements ☐

I do not agree with the above statements ☐

Appendix A.8: Ethical Approval Confirmation Second Letter

Keele UNIVERSITY

31st August 2018

Dear Khaled,

PI: Khaled Abuhlfaia
Title: Factors Affecting the Quality of E-Learning In Universities; The Importance of Usability
Ref: ERP2397

Thank you for submitting your application for review. The proposal was reviewed by the Panel Chair. I am pleased to inform you that your application has been approved by the Ethics Review Panel.

If the fieldwork goes beyond the date stated in your application, or there are any amendments to your study you must submit an 'application to amend study' form to the ERP administrator at research.governance@keele.ac.uk. This form is available via https://www.keele.ac.uk/raise/researchsupport/projectassurance/researchethics/

If you have any queries please do not hesitate to contact me, in writing, via the ERP administrator, at research.governance@keele.ac.uk stating **ERP2397** in the subject line of the e-mail.

Yours sincerely
PP.

Dr Colin Rigby
Chair – Ethical Review Panel

Appendix B: Mapping Study Protocol Details

Appendix B.1: Change Record version 2.4

Document status	Version No.	Date	Changes Applied
Draft	1.0	15/06/2016	None
Revision	1.1	09/06/2016	Updating the research question,

Name	Description	Role
Khaled Abuhlfaia	Lead Researcher	Designing the protocol, extracted and reviewing all required data.
Dr Ed de Quincey	Reviewer	Reviewing the protocol and performing data extraction for assign random sample of studies.
Prof Pearl Brereton	Reviewer	Reviewing the protocol and performing data extraction for assign random sample of studies.

Appendix B.2 Protocol Development Team

Appendix C: Survey

Appendix C.1: Profiles of respondents

1. What is your age?
    1. 18–27
    2. 28–37
    3. 38–47
    4. 48+

2. What is your gender?
    1. Male.
    2. Female.
    3. Prefer not to say.

3. What is your level of study?
    1. Undergraduate.
    2. Postgraduate master's taught.

4. Where do you come from?
    1. UK.
    2. International.

5. Which School(s) do you currently study in?
    1. School of Health & Rehabilitation.
    2. School of Medicine.
    3. School of Nursing and Midwifery.
    4. School of Pharmacy.
    5. Keele Management School.
    6. School of Humanities.
    7. School of Law.
    8. School of Politics, International Relations & Philosophy.
    9. School of Social Science & Public Policy.
    10. School of Computing & Mathematics.
    11. School of Life Sciences.
    12. School of Physical & Chemical.
    13. School of Psychology.
    14. School of Geographical Sciences, Geology and the Environment.

Appendix C.2 Experience and duration of study using the virtual learning environment

1. When was the last time you used the VLE?
    1. Less than one week.
    2. Less than one month.
    3. More than a month.

2. How long have you been studying at Keele University?
    1. Less than one year
    2. One–two years
    3. Three or more years

Appendix C.3 System evaluation System Usability Scale

To what extent do you agree with the following statements?

Note: 1= Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree.

1. I like to use the VLE frequently.
2. I found the VLE unnecessarily complex.
3. I thought the VLE was easy to use.
4. I found the various functions in the VLE well integrated.
5. I thought there was too much inconsistency in the VLE.
6. I imagine that most people would learn to use the VLE very quickly.
7. I found the VLE very cumbersome/awkward to use.
8. I felt very confident using the VLE.
9. I need assistance to be able to use the VLE.
10. I needed to learn a lot of things before I could get going with the VLE.
11. If you would like to make any other comments about your use of the VLE, please use the space below and continue overleaf if necessary. Thank you for your participation and your contribution to this survey is greatly appreciated.

Appendix C.4: System evaluation

To what extent do you agree with the following statements?

Note: 1= Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree.

Usability

1. I like to use the VLE frequently.
2. I found the VLE unnecessarily complex.
3. I thought the VLE was easy to use.
4. I found the various functions in the VLE well integrated.
5. I thought there was too much inconsistency in the VLE.
6. I imagine that most people would learn to use the VLE very quickly.
7. I found the VLE very cumbersome/awkward to use.
8. I felt very confident using the VLE.

Learnability

1. I need assistance to be able to use the VLE.
2. I needed to learn a lot of things before I could get going with the VLE.

Perceived Usefulness (PU)

1. Using the VLE would probably help me to accomplish tasks more quickly.
2. Using the VLE would improve my study performance
3. Using the VLE in my study would increase my productivity
4. Using VLE would enhance my effectiveness at university
5. Using the VLE makes it easier to do my study.
6. Overall, I find the VLE to be useful in my study.

Perceived Ease of Use (PEOU)

1. I find the VLE flexible to be interacting with.
2. Interacting with VLE does not require a lot of mental effort
3. Overall, I find the VLE easy to use.
4. I find it easy to get the VLE to do what I want it to do.
5. It is easy for me to become skilful at using the VLE.

Attitude

1. I have self-confidence in using the VLE.
2. Using of the VLE in higher education is useful.
3. I will use the VLE even if the benefits would come in the future.

Appendix D: Predefined Tasks

Table D.1: Time weighted success rate in the First session

	Task1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12	Weighted success
Baseline	9	6	4	5	4	13	3	3	16	2	2	2	69
P1	1	1	1	1	1	1	1	0	1	1	1	1	66
P2	1	1	1	1	0	0	0	1	1	0	1	1	47
P3	1	1	1	1	0	0	1	1	0	1	1	1	36
P 4	1	1	1	1	1	0	1	0	1	1	1	1	53
P 5	1	1	1	1	0	1	1	1	1	1	1	1	65
P6	1	1	1	1	1	0	1	1	1	1	1	1	56
P7	1	1	1	0	0	1	1	1	1	1	1	1	60
P8	1	1	1	0	1	1	1	1	1	1	1	1	64
P9	1	1	1	1	0	1	1	1	1	1	1	1	65
P10	1	1	1	1	1	1	1	1	1	1	1	1	69
P11	1	1	1	0	1	1	0	0	1	1	1	1	58
P12	1	1	1	1	1	1	1	0	1	1	1	1	66
P13	1	1	1	1	1	0	1	1	1	1	1	1	56
P14	1	1	1	1	0	1	1	1	0	1	1	1	49
P15	1	0	1	1	0	0	1	1	1	1	1	1	46
P16	1	1	1	1	0	0	1	1	1	1	1	1	52
P 17	1	1	1	0	1	1	1	1	1	1	1	1	64
P 18	1	1	1	1	0	0	0	0	1	1	1	1	46
P19	1	1	1	1	1	1	1	0	0	1	1	1	50
P20	1	1	1	1	0	0	0	1	1	0	1	1	47
P 21	1	1	1	1	1	0	0	0	1	1	1	1	50
P 22	1	1	1	0	1	1	0	0	1	1	1	1	58
P 23	1	1	1	1	0	1	1	1	0	0	1	1	47
P 24	1	1	1	1	1	0	1	0	0	1	1	1	37
P 25	1	1	1	1	0	1	1	1	0	1	1	1	49

Table D.2: Time weighted success rate in the second session

	Task1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12	Weighted success
BaseLine	9	6	4	5	4	13	3	3	16	2	2	2	69
P1	1	1	1	1	1	0	1	0	0	0	1	1	35
P2	1	1	1	1	1	1	1	1	0	0	0	1	49
P3	1	1	1	0	0	0	1	1	1	0	1	1	45
P 4	1	1	1	1	1	1	1	1	1	1	1	1	69
P5	1	1	1	1	1	1	1	1	1	1	1	1	69
P6	1	1	1	1	1	1	1	1	1	1	1	1	69
P7	1	1	1	1	1	0	1	1	1	1	1	1	56
P8	1	1	1	1	1	1	1	1	1	1	1	1	69
P9	1	1	1	1	0	0	1	1	1	1	1	1	52
P10	1	1	1	1	1	0	1	1	1	1	1	1	56
P11	1	1	1	1	1	1	1	1	1	1	1	1	69
P12	1	1	1	1	1	1	1	1	1	1	1	1	69
P13	1	1	1	1	0	0	1	1	1	1	1	1	52
P14	1	1	1	1	0	1	1	1	0	1	1	1	49
P15	1	1	1	1	1	0	1	1	0	1	1	1	40
P16	1	1	1	1	0	0	1	1	0	1	1	1	36
P 17	1	1	1	1	1	1	1	1	1	1	1	1	69

Table D.3: Participant 1 Session1 Completion Rate

Participant	Task	Time baseline	Weighted success	Session 1: completed tasks
P01	T01	9	9	Yes
P01	T02	6	6	Yes
P01	T03	4	4	Yes
P01	T04	5	5	Yes
P01	T05	4	4	Yes
P01	T06	13	13	Yes
P01	T07	3	3	Yes
P01	T08	3	0	No
P01	T09	16	16	Yes
P01	T10	2	2	Yes
P01	T11	2	2	Yes
P01	T12	2	2	Yes
Total	T12	69	66	11